INTERIM REPORT

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JOINT EXPERIMENTAL PROJECT BETWEEN SOUTHWEST REGION OF THE MINISTRY OF THE ENVIRONMENT AND GROUP DELTA IN THE STORAGE AND RENOVATION OF SEWAGE EFFLUENT BY CONVERSION TO SNOW

1982

Ontario

Ministry
of the
Environment

INTERIM REPORT

Joint Experimental Project
Between
Southwest Region of the Ministry
of the Environment and Group Delta
in the
Storage and Renovation
of Sewage Effluent by
Conversion to Snow

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Technical Support Section
1982

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CONCLUSIONS

The joint experimental project between the Southwestern Region of the Ministry of the Environment and Group Delta in the making of the snow from lagoon wastewater provided the following conclusions.

1. The manufacturing of snow from lagoon wastewater appears to be a consistent and reproducible process under similar weather conditions.
2. The transformation of sewage effluent (lagoon contents) into snow for storage and renovation appears to be a viable sewage treatment alternative.
3. The concentrations of the chemical parameters appears to be reduced by both instantaneous reactions and with time through exposure.
4. The chemical concentrations were reduced to near secondary treatment quality within 19 days (as shown by grid sampling) and better than tertiary treatment quality in the ponded water on the site after spring melt.
5. The bacteriological levels of coliform, fecal coliform and <u>Pseudomonas</u> <u>aeruginosa</u> in the manmade snow were initially typical of chlorinated secondary effluents. Fecal streptococci exhibited a significant resistance to the snow-making process; however, after 19 days of exposure the levels also decreased to concentrations typical of chlorinated secondary effluents.
6. Aerosolization of bacteria in lagoon wastewater resulted in concentrations similar to levels reported adjacent to aeration sections of secondary treatment plants.
7. Pathogenic bacteria in the aerosols were essentially non-detectable using a standard impactor sampler according to methods reported in the literature.

RECOMMENDATIONS

On the basis of the data obtained from the first year of study, the following recommendations are forwarded.

1. That the study proceed with the development of experiments in an attempt to understand the phenomena involved in the renovation of wastewater through the snow making process.

2. That additional on-site instrumentation and monitoring equipment be provided.

3. That the feasibility of using the atomization chamber as a site of disinfection in conjunction with the addition of specific disinfectants be assessed.

4. That perimeter ditching or some type of containment equipment be used to measure various parameters in the runoff.

5. That additional aerosol samplers be employed to better define the degree of aerosolization and determine the distance travelled during the snow making process.

6. That additional pathogenic bacteria, including coliphage analyses be performed on the raw wastewater and resultant snow.

INTRODUCTION

This interim report presents the results from the first year of a joint experimental project sponsored by the Southwest Region of the Ministry of the Environment and Group Delta to evaluate the making of snow from sewage effluent. Group Delta was responsible for the design and construction of the facilities while the Southwest Region of the Ministry of the Environment was responsible for sampling and analysis.

The purpose of the study is to determine if the manufacturing of snow from lagoon wastewater was an alternative treatment and storage option and is not intended for re-use or recycling on ski hills.

Thirty-five different snow making runs were conducted between January 6, 1982 and March 9, 1982. Samples to assess 16 different chemical parameters and a minimum of 4 microbiological parameters were obtained during each run, both for lagoon wastewater and "snow-fluent" (resultant man-made snow). Bacterial aerosol sampling was also undertaken during 32 different runs. Background natural snow was sampled along with samples in the artificial snow field to evaluate comparative changes with time. In total, over 2800 chemical and 1000 microbiological tests were conducted during this first year of study.

BACKGROUND

Sewage treatment for small communities, seasonal resort developments and small industries is an expensive undertaking throughout Ontario. One of the least expensive methods of treating sewage or wastes is the facultative

lagoon system. While such lagoons provide adequate and flexible waste treatment for many municipalities, major disadvantages of the lagoons in some situations are the large amount of land required and their poor removal efficiencies during some winter months. The land requirement varies with serviced population and discharge mode. Storage requirements normally vary from four to twelve months, which sometimes results in removal of excessive agricultural land from production and high land acquisition costs.

In order to reduce land requirements, some lagoons are being converted to full or partial aeration to inhibit formation of toxic hydrogen sulphide and to allow a continuous discharge in the winter. However, this drastically affects the operational costs of the lagoons. The timing of spring discharge is supposed to correspond to the spring melt. This feat is hard to achieve because of the variable timing of the spring melt, structural limitations at the lagoon outfall and the frequent need for chemical addition (by boat) for phosphorus reduction. As a result, the benefit of the spring snow melt for dilution is rarely maximized and in many cases the high flows are missed altogether.

In 1974, Wright McLaughlin Engineers (Denver, Colorado) undertook an experimental project sponsored by the Upper Yampa Water Conservation District. The experiment was the making of artificial snow from sewage effluent.

The test data indicated that sewage effluent can be stored in the form of snow, and the process provides a beneficial treatment effect during the snow making process and storage period. Snow was made six times during their study with the concentrations in the snow melt runoff resembling tertiary treatment.

This research project conducted by the Southwest Region of the Ministry of the Environment and Delta Group was a follow-up and confirmation of the work done in 1974 by Wright McLaughlin.

PROJECT LOCATION

The site chosen for the snow making experiment was near Collingwood beside the existing sewage lagoons servicing Blue Mountain Resorts Limited (Figure 1). The actual snow making site was on an old grassed airfield runway surrounded on three sides by scrub land and on the fourth by the sewage lagoons. All the property surrounding the site was owned by Blue Mountain Resorts Limited.

The soils information for the site was taken from the test pit borings done approximately 200 meters to the north for the construction of the third cell of the sewage lagoons. The topsoil is approximately 20 to 25 cm thick overlaying 25 to 30 cm of silty clay. The next 100 cm or so is brown clay with blue clay beneath. Test holes were dug at the test site and similar soil conditions were found.

The source of sewage for the lagoons was the resort development at Blue Mountain. This includes accommodations, restaurant, lodges and other facilities to accommodate the 350,000 skier visits per season.

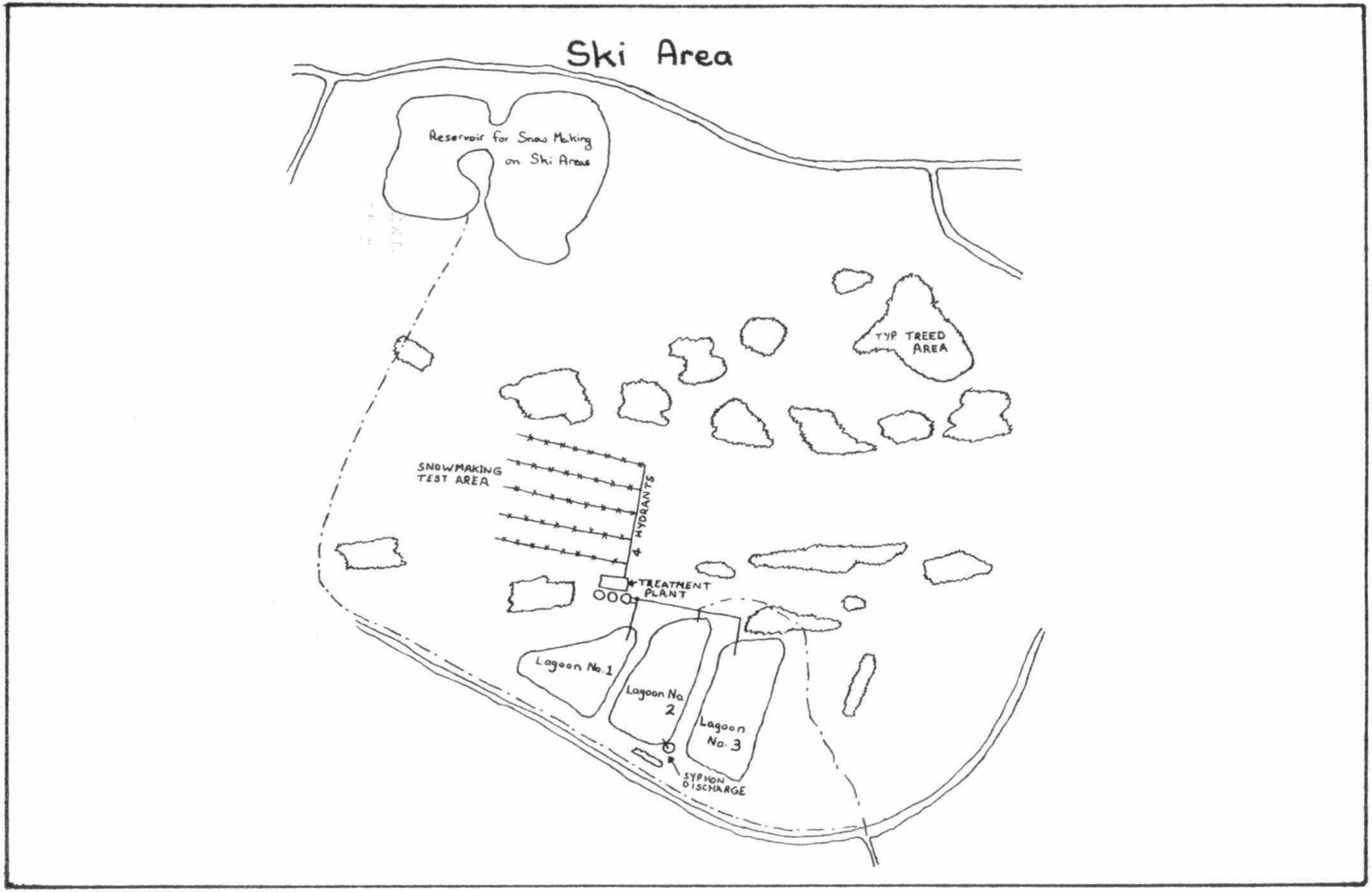

Figure 1. Location of experimental snow making facilities

DESCRIPTION OF PILOT PLANT

The pilot plant, located at Blue Mountain Resorts Limited, Collingwood, Ontario, was composed of the following:

- effluent storage tanks
- an effluent pumping system
- atomizing chamber
- compressed air system
- air/water snowmaking guns

(see figure 2)

Lagoon wastewater was pumped from the first sewage lagoon with a 5 HP submersible gasoline pump into three 19,000 liter (5,000 U.S gallon) storage tanks. The tanks were joined in parallel, and wastewater could be pumped from one tank to another and from the atomizing chamber to the tanks using two 10 HP horizontal electric pumps. A 25 HP horizontal electric pump, capable of pumping 570 L/min (150 gpm) at a maximum pressure of 1660 kPa (240 psi) was used to pump wastewater from the storage tanks to the snowmaking guns or the atomizing chamber. It was possible, with this arrangement of pumps and valves, to circulate the fluid from one storage tank or tanks through the atomizing chamber for any number of passes, or to by-pass the chamber totally sending the fluid directly to the snowguns.

The atomizing chamber enabled the mixing of pressurized effluent and air using an aluminum "PIT" model snowgun nozzle (Figure 3). The nozzle mixed the effluent and air, forming droplets of effluent approximately 200 microns in diameter. The mixture was sprayed on an impact cone located 1.2 m (3.25 ft) from the nozzle inside the chamber. The impact cone was used to increase the turbulence of effluent droplets. The chamber was at atmospheric pressure.

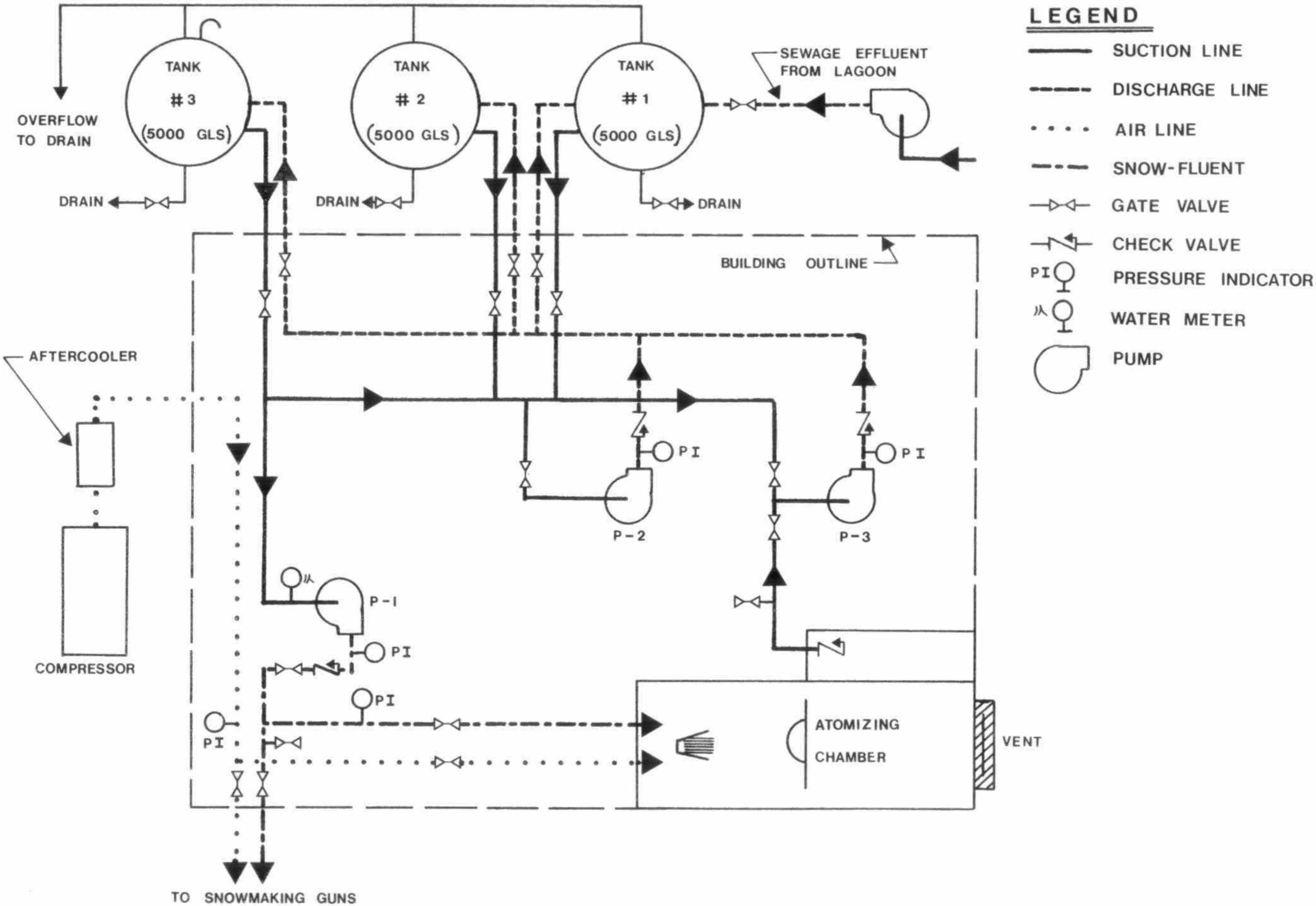

Figure 2 Sewage treatment plant schematic used during experiment

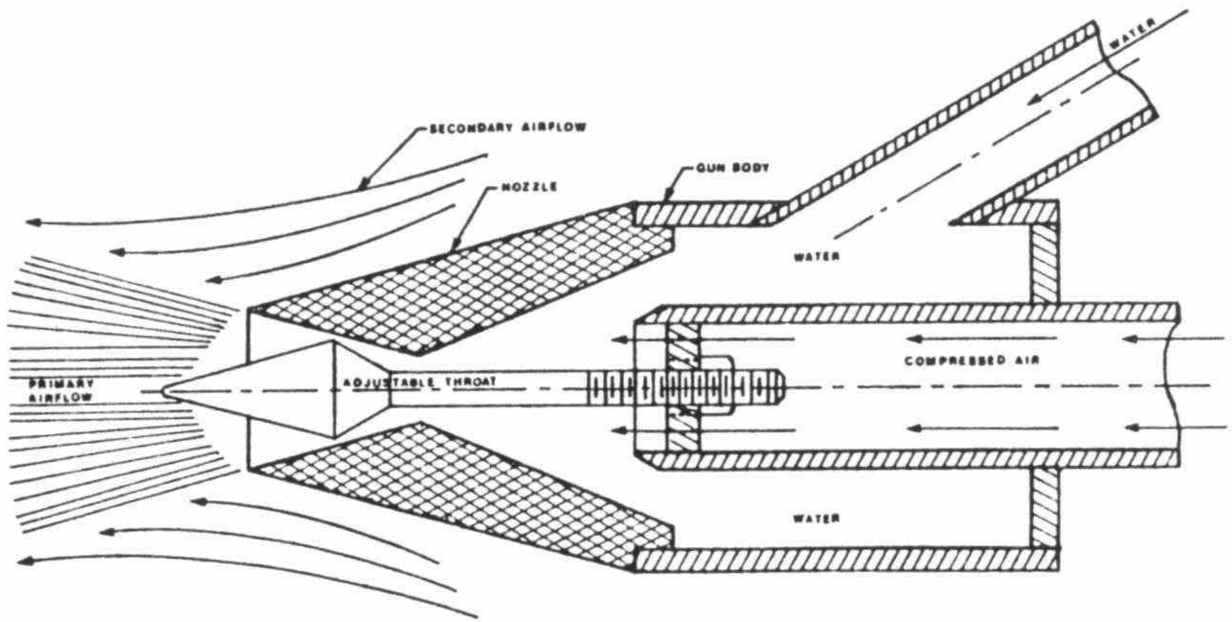

Figure 3. Cut-away view of a snow gun

The four snowmaking guns used at the test plot were connected in parallel and sled mounted with nozzles of the same type used in the atomizing chamber.

Air was supplied to the atomizing chamber and the snowguns by a portable diesel compressor capable of producing 20 m^3/min (700 cfm) at a pressure of 760 kPa (110 psi). Air leaving the compressor has a temperature of 60°C (140°F). The air was then passed through an air aftercooler to lower its temperature to approximately 4°C (40°F) before passing it on to the snowmaking guns or atomizing chamber.

Meters, pressure gauges, and taps were located so that the flow, pressure, and samples of the effluent, and pressure of the air going to the chamber and guns could be monitored. The compressed air and the effluent flow rates were adjustable by use of valving within the system to allow proper air-to-water ratios to meet the varying temperature and humidity conditions at the site to produce snow.

SAMPLING METHODS AND ANALYSIS

Liquid samples were collected in standard Ministry of the Environment sample bottles from sampling taps in the pilot plant. These samples were refrigerated and returned for analysis at the Ministry of the Environment Laboratory in London within 48 hours.

The snow samples were collected immediately after completion of a test run. Samples for chemical analysis were collected in wide-mouth 4.5 litre plastic jugs while samples for bacterial analysis were collected in presterilized 900 ml wide-mouth glass containers. These

samples were kept frozen until returned to the Ministry of the Environment's laboratory in London and were subsequently thawed at 41.5^{o}C prior to analysis. Additional snow samples were taken from the vicinity of the site on the dates shown in the same types of containers to provide a comparison with background samples and changes in quality of the snow with time.

During the last half of the sampling period, a large collector plate was placed on the ground, to guarantee the snow sampled was made during that run. After the samples were taken, the remaining snow was cleaned from the collector plate and it was repositioned to collect snow from the next run.

A Gelman six-stage aerosol impactor was utilized for aerosol sampling; however, as the sampling was conducted during sub-zero temperatures, modifications to the sampling unit were necessary to prevent freezing of agar plates within the impactor unit. The impactor head was contained in a plywood box (18 mm material) lined with 5 cm, thick density styrofoam with an opening to allow air to pass in to the sampling unit. Two small 115-volt, 100-watt thermostatically controlled heaters were installed in the box to maintain a constant temperature within the impactor head regardless of the outside ambient temperature. Thermometers installed in the sampler boxes, specifically in the discharge air tube allowed for temperature measurements within the impactor head. The variable speed pumps drawing air through the Gelman impactor heads were calibrated using a Precision Wet Test Meter manufactured by the Precision Scientific Company. An illustration of the modified design of the sampler is included in Figure 4. In order to determine the potential effect of placing the impactor sampling unit in the box, a comparison involving 2 identical

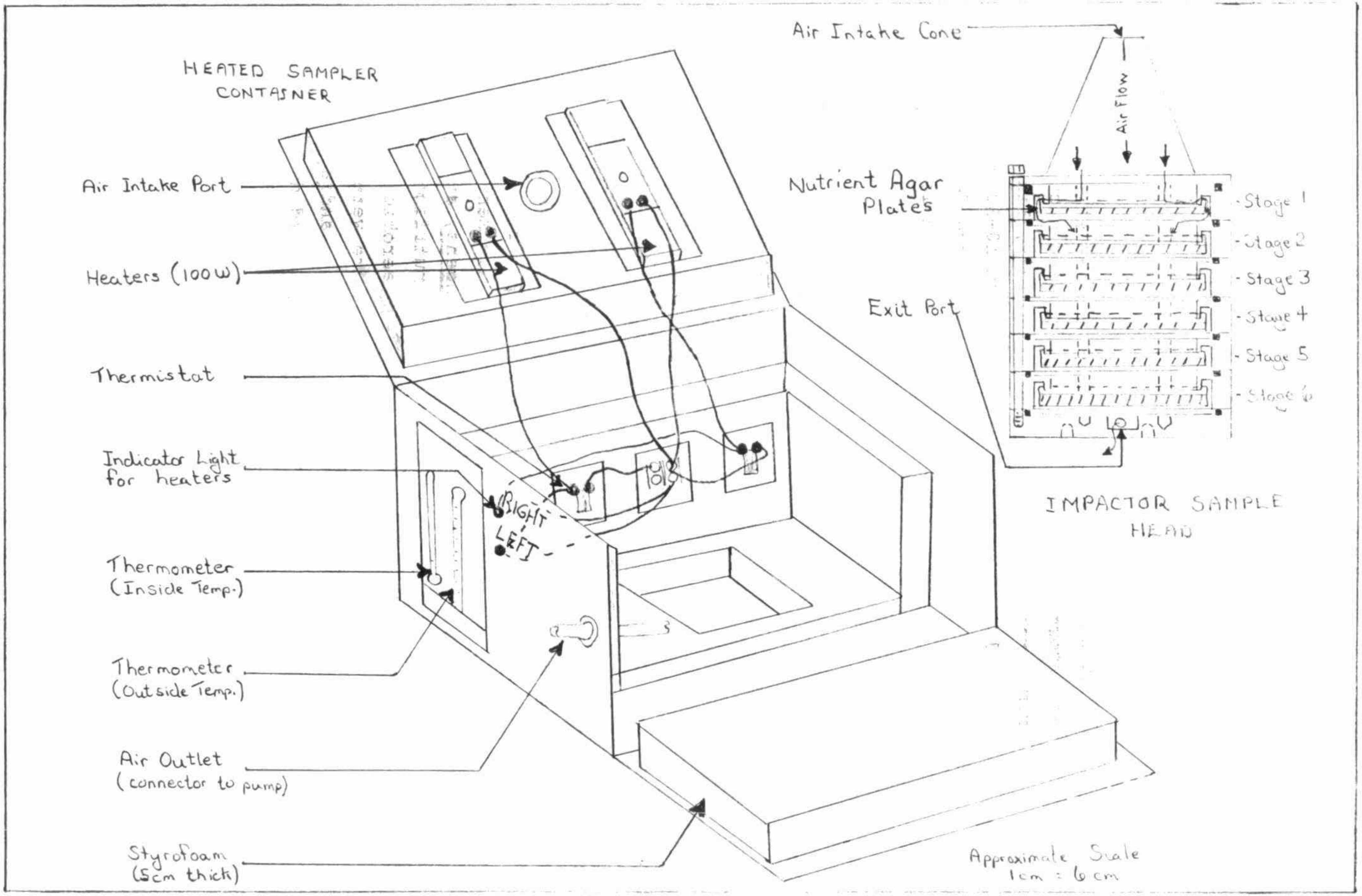

Figure 4. Diagram showing cross-section of microbial impactor head and heated container for impactor sampler

sampling units was undertaken. They were placed side-by-side (one in a box and one out of a box) 2.5 m above the ground adjacent to the aeration tank at secondary sewage plant. Five independent sampling runs were conducted of 15 minute duration. Aerosol samples obtained from the Gelman impactor sampling device were recovered using nutrient agar as the isolation medium. Non-selective media such as this have been recommended for recovering stressed bacterial cells from aerosols (Crawford and Jones, 1979, Kingston, 1971). Actual sampling periods ranged from 10-30 minutes; thereby not exceeding the time that would cause dehydration of the surface of the agar and thus result in a less efficient recovery of bacterial cells.

Following the incubation of nutrient agar plates at 35°C for 24 hours, a replicate plating procedure utilizing velveteen covered stamps was employed to transfer bacterial colonies to various selective-differential media. The standard pollution indicator organisms, total coliforms, fecal coliforms, and fecal streptococci were recovered initially on nutrient agar plates. During specific runs, the bacterial pathogens, *Salmonella sp.*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Clostridium perfringens* were also detected using a similar transfer technique. The media used to recover both the bacterial indicators and pathogens previously mentioned are listed in Appendix C. *Clostridium perfringens*, an anaerobic bacterium was recovered by incubating the nutrient agar plates from the impactor directly in an anaerobic jar in the field. The incubation period and temperature were approximately 24 hours and 22°C respectively, and a temperature of approximately 15°C was maintained during transport to the laboratory. BBL gas-pak generators were utilized to create the anaerobic atmosphere in the jars. Subsequently, colonies that developed were replicated onto

Plate 1. Top: Picture showing the making of snow on the test plot.

Bottom: Picture showing the making of snow in background with upwind aerosol sampler in foreground.

the selective medium, CP agar and re-incubated anaerobically for 24 hours at 44.5°C. Once colony numbers were determined, concentrations of various bacterial types were calculated on a basis of a cubic meter of air. The sampling flow rate and time periods were utilized for the calculation of bacterial numbers per cubic meter of air.

In order to establish the efficiency of transfer of various colony types from nutrient agar plates to the selective media, a series of plating efficiency experiments were conducted. A pure culture suspension of *Escherichia coli*, *Streptococcus fecalis*, *Salmonella sp.*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* was plated on nutrient agar. The resulting pure cultures were replicated onto the appropriate selective medium and incubated accordingly. From colony numbers determined on nutrient agar plates and those on the selective media, a percent recovery of indicator and pathogenic bacteria was determined. Results of these percent recovery experiments are displayed in Appendix C.

No monitors were installed around the test site to monitor groundwater because of the relatively impermeable nature of the soil. However, surface grab samples of soil were taken prior to and after the snow making season to monitor possible changes in the chemical soil composition. No analysis of the soil has been done to date. The intent is to collect more samples prior to and after the next snow making season with all samples then being submitted for the most appropriate analyses.

Field Procedures

Previous to snow production, control samples of natural snow were taken at locations 35 and 70 meters downwind of the snow production site. During all snow production runs control samples were taken at approximately 20 meters upwind from the snow guns while downwind samples were taken in the centre of the snow accumulation. The sampling of the aerosol produced by snow making involved locating one unit 70 meters downwind from the functioning snow gun(s) and occasionally at 130 meters downwind. The control upwind location was located 10 meters behind the operating snow guns. Snow production commenced by pumping the wastewater from lagoon No. 2 to the storage tanks. The wastewater was then forced at approximately 1380 kPa pressure mixed with air at 414 kPa pressure through one or two snow guns at various flow rates. For specific snow production runs, the wastewater was cycled through a high velocity atomizer prior to being used for snow production. Routine snow making runs were conducted as previously mentioned under field conditions described in Table 1.

Following a period of five days, the snow accumulation sites of the previous runs 1 through 7 inclusive were sampled preceding the next snow production runs.

To aid in the assessment of the effect of cycling the lagoon wastewater through the high velocity atomizer, a wastewater cycling experiment was conducted. This involved the passing of the lagoon wastewater through the atomizer at various flow rates and at specific air and water pressures. Samples of wastewater before and after each treatment were taken.

Table 1. Field operational conditions

Snow Production Run Number	Number of Cycles in Atomizer	Number of Snow Guns	Flow Rate of Wastewater l/s	Aerosol Sampler Location m	Percent Relative Humidity	Temperature °C
1	0	1	N.A.	70	N.A.	-2.0
2	0	1	N.A.	70	54.2	-4.0
Snow samples taken 2 h after routine samples at run 2						
3	1	1	N.A.	70	62.8	-6.0
4	0	2	N.A.	70	67.2	-10.5
5	0	2	N.A.	70	63.1	-8.5
6	1	2	N.A.	70	65.1	-12.5
7	0	2	N.A.	70	76.3	-11.5
Snow accumulation sites of runs 4-7 were sampled 5 days after run 7.						
8	0	1	N.A.	70	67.1	-9.5
9	0	1	N.A.	70	65.2	-8.5
10	0	1	N.A.	70	63.9	-9.0
11	0	1	N.A.	70	79.2	-9.0
12	0	1	N.A.	70	79.2	-9.0
13	0	1	N.A.	70	82.1	-9.0
14	0	2	N.A.	70	68.2	-6.0
15	0	2	N.A.	70	61.2	-6.0
16	0	2	N.A.	70	71.0	-7.0
17	0	1	1.2	70	67.0	-7.0
18	0	1	1.2	70	67.0	-8.0
19	2	1	1.1	70	67.0	-12.0
20	2	1	11.4	70	67.0	-12.0
21	0	2	4.5	130	60.0	-7.0
22	0	2	3.0	70	60.0	-6.0
23	0	2	3.0	70	60.0	-6.0
24	0	2	3.0	70	60.0	-6.0
25	0	2	3.0	70	N.A.	N.A.
26	0	2	3.0	70	60.0	-5.0

Table 1. Field operational conditions

Snow Production Run Number	Number of Cycles in Atomizer	Number of Snow Guns	Flow Rate of Wastewater l/s	Aerosol Sampler Location m	Percent Relative Humidity	Temperature °C
27	1	1	0.8	70	67.8	-5.0
28	1	1	0.8	70	67.1	-5.0
29	0	1	1.8	70	67.1	-4.0
30	0	1	1.8	70	67.1	-2.5
31	0	1	3.0	70	64.6	-2.0
32	0	1	0.8	70	65.2	-2.0
Snow samples taken from entire snow accumulation are following 19 days exposure.						
33	0	1	2.7	70	75.0	-6.0
34	0	1	1.9	70	75.0	-5.0
35	0	1	0.3	70	75.0	-1.0

The effect of cycling the lagoon wastewater followed by snow production at reducing bacterial concentrations in the snow was further studied during snow production runs 3, 6, 17, 19, 20, 27 and 28 using sampling procedures described previously.

Independent of typical snow production runs, snow was accumulated over a 6 hour period on one day using a single gun at a site adjacent to the routine locations in order that the snow could be sampled with time and remain unaffected by future runs. Seven days later, from the resulting 60 cm deep snow pile, samples taken in the bottom 10 cm, middle 10 cm and top 10 cm were analysed to observe the affects of layered conditions in a snow pile with time. This pile was sampled on three additional occasions at 10, 29 and 49 days at identical depths.

During a period from January 6, 1982 to January 29, 1982 the previously described snow production runs were conducted. Nineteen days later, the entire snow accumulation area was sampled. As the artificially produced snow was very granular in appearance, differentiation from natural occurring snow was readily possible.

RESULTS AND DISCUSSION

The experiment conducted during the winter of 1981-82 at Blue Mountain involving artifical snow making from lagoon wastewater provided basic data and operational experience related to treatment and storage of sewage effluent as snow during the winter period. This innovative approach to sewage treatment resulted in dramatic changes to the lagoon wastewater during its transformation and storage as snow. All the phenomena and reactions at this time are not completely understood and there are many "black boxes" to be opened. However, the process appeared to be consistent and reproducible.

The results of the chemical and bacteriological analyses are shown in Tables 2 through 12 and Tables A1 to A4 of the Appendix. The chemical data for specific runs are presented in percent difference while the bacterial data are in log change. The information showing the effect of atomizing and storage of snow with time is also presented in Tables 2, 3, 8 and 10. The tables (5, 6 and 11) showing grid sampling or ponded water are in actual concentrations. All actual concentrations for the runs are provided in the Appendix.

The discussion of results contains some unproven hypotheses and theories that must be verified during the next stage of the project. Some experiments are presented and discussed which were undertaken to help identify and understand various phenomena. One must keep in mind that the experimental project was to determine the effectiveness of the process on sewage effluent and not on the near raw sewage which was utilized. However, the percent changes that were measured would also be expected to occur using wastes of weaker strength.

The chemical results are presented and discussed on a parameter-by-parameter format, while the bacteriological results are presented and discussed on a run-by-run basis. For ease of presentation, the chemical and bacteriological results have been separated.

Chemical Parameters

The following is a presentation of the more interesting chemical parameters in respect to lagoon wastewater and resultant instantaneous concentrations in the snowfluent. The affects of the storage, grid sampling and melt water are presented after the instantaneous results.

The typical BOD_5 in the lagoon wastewater was 50 mg/l, ranging from 36 to 122 mg/l. The resultant instantaneous snow concentrations ranged from 19 to 104 mg/l. As shown in Table 2, both increases and decreases were observed. This was thought to be a result of pulverizing the organics into smaller pieces making them more oxidizable by bacteria and/or some of the organics being entrapped in the bonding during the formation of suspended solids. The immediate changes were expected to be related to changes in decay rates. BOD_{20} were done along with BOD_5 on runs 33, 34 and 35 (appendix) to prove or disprove our assumption. It was speculated that the ultimate BODs in the lagoon wastewater and snowfluent would be similar. However, in all cases, the BOD_{20} in the snowfluent were at least 58% less than the lagoon wastewater.

The suspended solids in the lagoon wastewater were in the 30 to 40 mg/l range. The concentrations in the resultant snow increased to typically 100-200 mg/l. These

Table 2. Chemical results expressed as % difference during the manufacturing of snow from sewage.

Run #	Air Temp °C	Date	Bod_5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrate	Ca	Mg	Hardness	Fe	Na	SO_4
Snow sampled		Jan 6																
Run 1 24 hr later	-4	Jan 7	-73	606	-83	13	-68	-92	-97	-79	100	400	-84	-85	-85	1051	-86	-77
Jan 6; Jan 7																		
Run 2 immed	-4	Jan 7	-18	72	7.2	19	14	-38	-23	4	700	800	-22	4	-13	25	-4	5
2 hrs later		Jan 7	-14	108	4	22	3	-46	-36	-11	300	900	-36	1	-24	57	-8	-5
Run 3	-6	Jan 7	-14	95	7	16	3	-37	-28	-5	600	800	-35	4	-22	-6	14	2
Run 4 Gun 3	-10.5	Jan 13	-47	-45	-65	23	-70	-82	-68	-69	50	300	-69	-69	-69	-56	-31	-64
Gun 4		Jan 13	44	286	-22	18	-23	-54	-22	-25	650	100	-36	-22	-32	39	-19	-22
Run 5 Gun 1	-8.5	Jan 13	60	329	-5	25	-12	-79	-19	-7	700	200	-43	-10	-32	28	-4	-7
Gun 2			69	325	-90	22	2	-68	-7	14	800	200	-32	2	-20	31	-4	2
Run 6 Gun 1	-12.5	Jan 14	67	335	5	25	0	-81	-29	-2	400	500	-29	0	-20	70	4	-3
Gun 2			70	223	4	25	-7	-82	-27	1	500	500	-28	0	-19	25	4	-3
Run 7 Gun 3	-11.5	Jan 14	58	227	2	28	-7	-82	-32	-2	600	400	-26	-1	-18	22	1	-5
Gun 4			62	206	2	30	-9	-82	-34	-4	600	500	-29	-1	-20	22	-1	-6
Run 8 Gun 1	-9.5	Jan 19	7	811	18	23	-3	-76	13	1	0	0	-66	-2	-43		13	-8
Gun 1			7	837	13	20	-1	-64	11	3	0	0	-55	22	-35		13	-8
Run 9 Gun 2	-8.5	Jan 19	2	624	-12	22	-22	-80	11	1	0	0	-67	0	-43		-10	-7
Gun 2			2	631	-13	22	-23	-80	15	-1	0	0	-69	2	-44		-10	-1
Run 10 Gun 2	-9.0	Jan 19	26	827	3	23	-5	-79	10	13	0	0		3			5	-8
Gun 2			24	734	4	18	-5	-69	2	11	0	0		2			7	-8
Run 11 Gun 2	-9.0	Jan 19	9	668	9	18	-6	-73	6	7	0	0	-59	1	-36		7	-11
Gun 2			13	729	8	20	-8	-76	5	12	0	0	-64	2	-40		4	-11

Table 2. Chemical results expressed as % difference during the manufacturing of snow from sewage.

Run #	Air Temp °C	Date	BOD_5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrate	Ca	Mg	Hardness	Fe	Na	SO_4
Run 12 Gun 2	-9	Jan 19	-4	748	4	21	-12	-76	-4	15	100	0	-60	3	-37		4	-12
Gun 2			0	752	2	21	-7	-75	-6	13	100	0	-62	-1	-40		4	-13
Run 13 Gun 2	-9	Jan 19	-60	9	-63	25	-68	-89	-75	-71	200	200	-73	-61	-69		-65	-60
Gun 2			-34	200	-34	24	-45	-90	-72	-48	100	200	-71	-32	-58		-36	-32
Run 14 Gun 1	-6	Jan 20	-45	64	-39	22	-49	-85	-44	-43	100	400	-71	-40	-60		-37	-36
Gun 2			-16	250	-13	17	-17	-72	-25	-14	100	400	-48	-11	-35		-13	-8
Run 15	-6	Jan 20	0	379	7	17	-7	-75	-5	+16	100	0	-50	-1	-33		2	-9
Run 16 Gun 1	-7	Jan 20	-6	409	8	19	-5	-77	-4	13	100	0	-56	2	-36		7	-10
Gun 2			-2	472	8	20	1	-79	1	12	100	0	-59	2	-38		6	-10
Run 17 Gun 4	-7	Jan 26	111	187	20	14	-8	-21	8	-9	1100	800	-26	-1	-18		20	28
Run 18 Gun 4	-8	Jan 26	80	323	19	22	2	-56	-9	6	800	700	-43	-1	-28		8	10
Run 19 (Atomized twice)	-12	Jan 26	89	318	14	19	3	-46	-5	7	1000	800	-33	2	-21		8	7
Run 20 Gun 4 (Atomized twice)	. -12	Jan 26	83	336	19	24	2	-57	-5	4	1100	700	-46	-2	-31		3	4
Run 21 Gun 2	-7	Jan 27	-51	-26	-69	21	-73	-75	-74	-71	100	500	-71	-68	-70		-71	-57
Gun 4		Jan 27	45	436	3	23	-8	-54	-1	-2	400	900	-42	-2	-29		0	10
Run 22 Gun 2	-6	Jan 27	30	88	-22	9	-23	-32	-8	-20	400	700	-27	-24	-26		-26	-21
Gun 4		Jan 27	73	484	9	20	5	-56	10	18	600	1000	-31	6	-18		4	13
Run 23 Gun 2	-6	Jan 27	36	236	9	18	9	-43	-23	5	500	1000	-25	2	-16		5	15
Gun 4		Jan 27	-4	11	-48	5	-32	-37	-50	-47	300	400	-44	-54	-48		-52	-46

Table 2. Chemical results expressed as % difference during the manufacturing of snow from sewage.

Run #	Temp °C	Date	Bod_5 (mg/l)	Air Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrate	Ca	Mg	Hardness	Fe	Na	SO_4
Run 24 Gun 2	-6	Jan 27	48	324	14	19	-4	-39	-25	0	500	1100	-21	9	-11		10	20
Gun 4			41	242	8	19	5	-44	-28	5	600	100	-25	6	-14		6	14
Run 25	Run stopped																	
Run 26 Gun 2	-5	Jan 27	32	220	10	18	1	-39	-38	-3	600	1000	-30	2	-19		3	12
Gun 4			32	236	10	20	4	-48	-36	1	700	1000	-32	3	-20		3	12
Run 27 Gun 4	-5	Jan 29	LA	12	-23	22	-31	-62	-36	-40	500	800	-43	-29	-38		-24	-27
Run 28	Sample Lost		LA															
Run 29 Gun 4	-4	Jan 29	LA	37	3	8	5	6	-15	-3	42	1100	6	6	6		9	3
Run 30 Gun 4	-2.5	Jan 29	LA	43	7	5	7	6	-9	-3	89	1000	4	3	4		9	-2
Run 31 Gun 4	-2	Jan 29	LA	59	3	7	2	0	-10	-7	7	1000	4	8	5		9	17
Run 32 Gun 4	-2	Jan 29	LA	147	-25	18	0	-26	-20	-8	-54	1000	-5	-2	-4		-16	12
Run 33	-6	Mar 9	-58 -15	419	6	12	28	-53	-15	0	100	0	-22	-1	-14		10	6
Run 34	-5	Mar 9	-62 -17	212	6	6	-1	-21	-31	-3	0	0	-3	2	-1		10	1
Run 35	-4.5 - -1	Mar 9	-70 -35	109	-26	5	-21	-33	-38	-27	0	0	-24	-29	-26		-25	-25

LA = lab accident

instantaneous increases in suspended solids are believed to be a result of insoluble carbonates forming during the freezing process. The decreases in calcium, and magnesium support this theory.

The total phosphorus in the lagoon wastewater ranged from 3-10 mg/l with little difference in most of the snow samples. The soluble phosphorus (filtered reactive phosphorus) varied from 2.5 to 9.0 mg/l, typically in the lagoon wastewater. The concentrations in the snow usually showed greater than a 50% reduction to the 1-3 mg/l range. These changes in phosphorus concentrations are again assumed to be related to the formation of the solids. The soluble phosphorus was bound to the major cations to form insoluble or slightly soluble compounds such as calcium phosphate. These insoluble or slightly soluble compounds were filtered or precipitated out in the analysis.

Free ammonia in the lagoon wastewater varied from 28 - 50 mg/l. Concentrations in the snow normally showed decreases in the concentrations but still ranged up to a maximum of 45 mg/l. These instantaneous changes in free ammonia are assumed to be a result of volatilization. The Kjeldahl nitrogen in the lagoon wastewater is similar to the free ammonia concentrations but 2-5 mg/l higher. Both increases and decreases in concentrations were noted in the resultant snow. The nitrate concentrations in the lagoon wastewater were normally 0.01 mg/l or less. While in the snow, they increased up to a maximum of 0.17 mg/l. Nitrate concentrations were normally less than 0.01 mg/l in the lagoon wastewater, while the snow contained approximately 1.1 mg/l. There appears to be a small amount of oxidation of nitrogen as shown by the nominal increases in nitrite and nitrate levels.

The pH in the lagoon wastewater ranged from 7.4 - 7.8 during the tests. The resultant concentrations in the snow were typically 8.5 - 9.5 pH units. This increase in pH is believed to be a result of the removal of carbon dioxide during the freezing process.

The lagoon wastewater contained between 80-100 mg/l calcium. The levels in the snow decreased to the 20-80 mg/l range. Similarily, the range of hardness in the lagoon wastewater sampled was 280-500 mg/l as $CaCO_3$, while the concentrations in the snow ranged from 200-350 mg/l. The changes in calcium and hardness are again assumed to be related to the increase in suspended solids during the formation of the snow.

The chemical results of the snow pile, to show percent change with time are presented in Table 3. Samples were taken of the top, middle and bottom of the pile immediately and 7, 10, 29 and 49 days after snow production. The BOD showed an increase immediately in the snow and then reduced to greater than 72% removal. The soluble phosphorus was reduced to greater than 90% removal, while the free ammonia showed greater than 85% reduction. After 49 days, the total phosphorus showed percent removal of 15 to 90 depending on depth of the sample. The actual concentrations of these parameters are shown in the Appendix.

The changes with time are a result of the continued oxidation, reduction, volatilization and migration of the solids through the snow pile. When water freezes, the ice crystals formed are pure water. Any impurities that may have been in the water are trapped between crystals which are held together by inner molecular bonds. With thermal changes, there is a tendency for each snow crystal

Table 3. Chemical results expressed as % difference showing the effects of storage as snow

Snow Pile		BOD_5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Sol	F.A.	Nitrogens Kjel	Nitrite	Nitrate	Ca	Mg	Hardness	Na	SO_4
Same Day		14	818	40	24	10	-82	-28	-28	300	0	-66	9	-41	36	-8
7 days	top	14	942	29	25	8	-73	-54	-48	200	0	-68	-7	-46	13	-7
	middle	-60	1050	-80	25	-28	-83	-78	-74	0	0	-70	-73	-71	-75	-73
	bottom	-57	398	-55	27	-86	-78	-84	-80	0	0	-79	-57	-71	-59	-58
10 days	top	LA	787	34	28	5	-82	-73	-63	200	0	-35	0	-22	21	6
	middle	LA	856	-75	30	-30	-89	-84	-80	0	0	-49	-76	-58	-76	-74
	bottom	LA	485	-68	29	-47	-87	-87	-83	0	0	-56	68	-60	70	-64
29 days	top	-60	818	-81	29	8	-93	-87	-86	0	0	-68	-69	-68	-77	-81
	middle	12	350	30	24	-12	-71	-83	21	200	0	-48	-7	-33	25	-6
	bottom	-74	776	-66	28	-33	-85	-91	-84	100	0	-72	-68	-70	-66	-67
29 days	top	-51	722	-37	29	0	-93	-84	-80	0	0	-49	-48	-49	-44	-53
	middle	-49	835	-16	28	-8	-86	-81	-74	100	0	-44	-30	-39	-23	-30
	bottom	-58	175	-54	26	-77	-86	-92	-88	0	0	-79	-60	-72	-55	-55
49 days	top	-72	681	-68	27	-15	-99	-87	-81	100	100	-68	-69	-68	-66	-69
	middle	-72	635	-38	29	-34	-91	-88	-79	200	100	-71	-46	-62	-36	-41

to reduce its surface area. This is accomplished by reduction of surface curvature and is called destructive metamorphism. In the later stages of "destructive" or equally temperature metamorphism, impurities migrate to the outer limits of the snow grains which are increasing in size (Wright-McLaughin Eg. 1975). In the event of short thaws, melt water from the upper layers of the snow pack carries impurities downward through the snow layers by gravity and capillary action. In extreme cold weather, concentrating of the impurities may occur as a result of sublimation from the snow pack. The reduction in chlorides in the snow pack with time would suggest that downward migration of the impurities was the main phenomenum occurring during our study to determine the effects of storage.

Another small experiment was conducted in an attempt to differentiate between the major phenomenum occuring during the snow project. The study was undertaken to determine if the noted changes were a result of the high velocity atomization and oxidation or if the changes were a result of the actual freezing of the water molecules. As shown in Table 4, no or very few changes were noted in the chemical quality as a result of running the lagoon wastewater through the atomization chamber. As a result of this experiment, it is felt that the changes in quality relate to the freezing process more than the high velocity atomization or oxidation.

Table 5 presents the results of grid samples taken at the locations shown in Figure 5 on February 17 across the snow making area nineteen days following a snow production run. The concentrations decrease with distance from the snow guns. However, these concentrations of BOD_5, phosphorus and the nitrogens even at the 9 stations nearest the snow guns resemble secondary treatment quality.

Table 4. Chemical results expressed as % difference showing effects of atomization chamber on waste water

Atomized Run #		Flow gal/min	BOD_5 (mg/l)	Susp Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	SO_4	Na
Test 1		80	8	2	-2	-1.6	-2	-1	-1	-4	0	0	4	-1	2	0	1
Test 2		60	0	-4	0	1.2	1	-1	-3	2	-	0	0	0	0	-2	1
Test 3	Run 1	36	3	-3	-4	-.1	-2	-1	-2	0	0	0	1	-2	0	3	1
	Run 2		-12	5	3	.8	-5	1	-3	0	0	0	1	0	-2	0	
Test 4	Run 1	55	5	-3	-4	1.3	0	-5	0	0	0	0	1	1	1	2	0
	Run 2	55	-10	3	-1	0	5	-1	1	2	0	0	1	2	1	2	0
	Run 3	55	-5	-8	-3	.4	2	-4	2	0	0	0	1	-1	0	0	0
	Run 4	55	0	-8	0	0.3	-2	3	1	0	0	0	-1	-2	1	1	0

Table 5. Chemical results of grid sampling snow field 19 days following a snow production run

Sampling Location	BOD_5 (mg/l)	Chloride	Susp Solids	pH	Phosphorus Total	Phosphorus Sol	F.A.	Nitrogens Kjel	Nitrogens Nitrite	Nitrate	Calcium	Magnesium	Hardness	Iron	Sodium	Sulphate
1	20	22.5	127.7	9.96	4.40	0.25	2.1	5.50	0.01	L0.1	39	8	130	3.2	13.5	8.5
2	27	39	113.8	9.91	5.30	0.25	4.9	9.00	0.02	0.2	39	10.2	140	1.7	24.2	16
3	7.6	14.5	12.8	8.96	0.54	0.20	0.6	1.40	0.01	0.4	9	2.4	32	1.1	9.8	6
4	11.2	31	25	9.92	2.22	0.45	2.4	4.6	0.04	0.4	34	7.0	114	1.75	20.6	9.5
5	16	33	66.9	9.73	1.40	0.50	1.2	3.15	0.04	0.5	22	7.0	84	2.2	24.5	12.5
6	9.6	43.5	31.4	9.36	0.94	0.50	1.6	2.70	0.02	0.6	13.5	4.2	51	1.66	29	10
7	8.4	17.5	15.3	9.08	0.66	0.25	0.4	2.3	0.01	0.3	10	2.8	37	1.15	12	6
8	14.8	33	28.2	9.81	1.28	0.50	0.9	2.6	0.04	0.4	19	6.6	75	1.72	23.5	10.5
9	16.4	40	18.6	9.82	1.56	0.50	1.3	3.2	0.05	0.5	24.5	8.2	95	1.37	30	12.5
10	3.6	2	15	8.16	0.06	L0.05	0.1	0.7	L0.01	0.1	1.5	0.2	5	1.17	0.9	1.0
11	2.0	1	14	7.45	L0.05	L0.05	0.1	0.4	L0.01	0.1	0.5	0.2	2	0.98	0.5	0.5
12	2.0	1.5	19.6	7.33	L0.05	L0.05	0.1	0.35	L0.01	0.1.	0.5	0.2	2	0.98	0.8	1.0
13	2.4	1	9.9	6.47	L0.05	L0.05	L0.1	0.15	L0.01	0.3	0.5	0.2	2	0.96	0.4	0.5
14	2.0	1	15.1	6.62	L0.05	L0.05	L0.1	0.25	L0.01	0.2	1.0	0.2	3	1.03	0.9	1.0
15	1.2	1	8.9	6.34	L0.05	L0.05	L0.1	0.15	L0.01	0.1	0.5	0.2	2	0.81	0.3	0.5
16	0.8	1	9.2	6.00	L0.05	L0.05	L0.1	L0.15	L0.01	0.1	0.5	0.2	2	0.89	0.5	0.5
17	1.4	0.5	7.9	4.75	L0.05	L0.05	L0.1	L0.10	L0.01	0.5	1.0	0.2	3	0.65	0.3	0.5
18	22	5.5	28.5	9.71	1.60	0.45	1.7	5.00	0.04	0.7	24.5	6.4	88	1.22	17.6	12.5
19	2.8	3.0	93.8	8.76	0.26	0.20	0.2	0.50	0.01	0.2	6.5	0.8	20	4.24	1.6	1.5
20	23.6	30	35.1	9.87	1.88	0.45	2.1	6.00	0.03	0.7	25	8	95	1.18	25.5	15.5
21	28	52.5	44.5	9.83	2.30	0.55	2.4	6.50	0.03	0.7	33	10.6	126	1.22	37.5	19

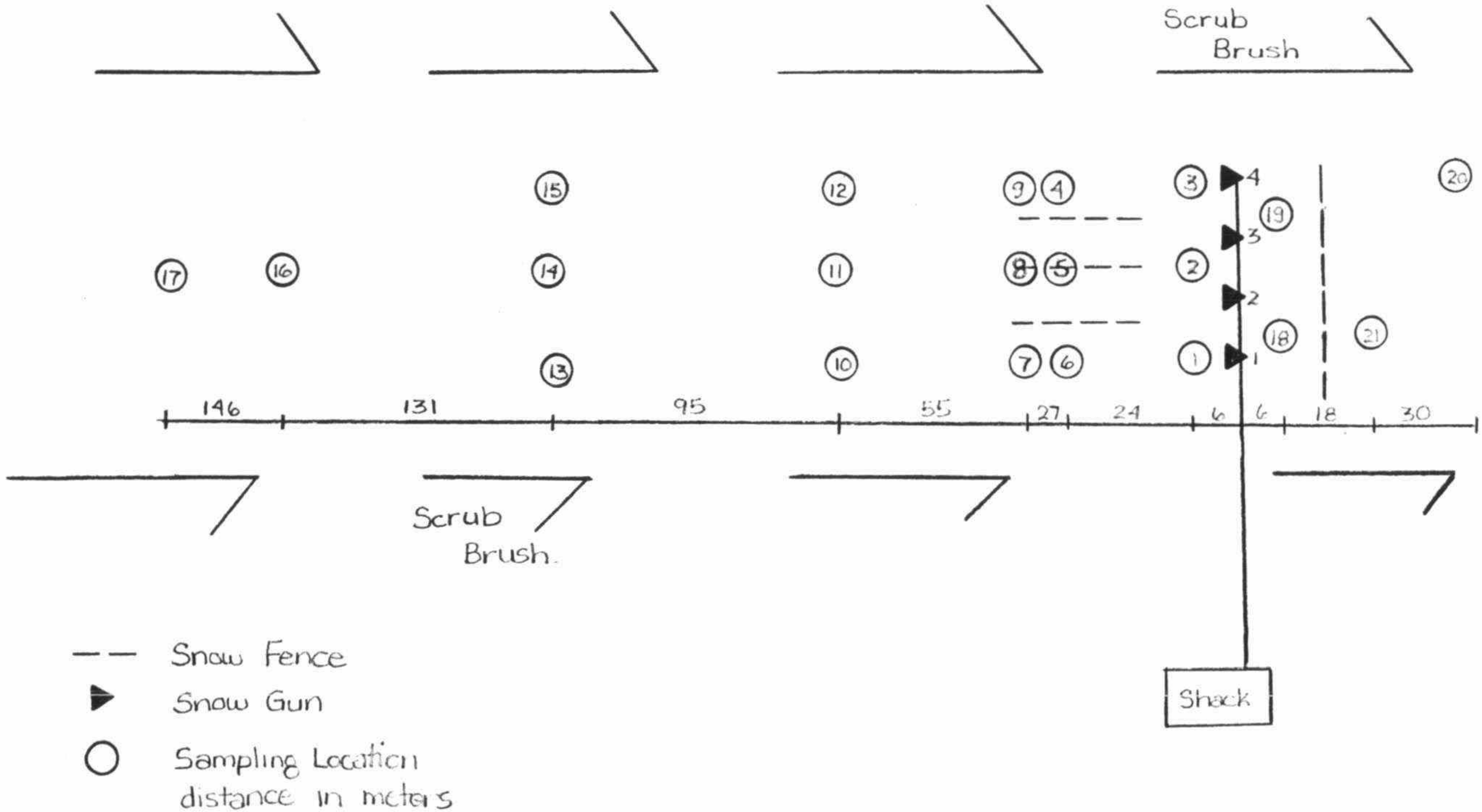

Figure 5. Locations within the grid sampled 19 days following a snow production run

The nine samples of melt water collected from our snow site are shown on Table 6. These samples were collected on two occasions from pools or depressions on the site. The BOD_5, total phosphorus and soluble phosphorus had maximums of 3.2 mg/l, 0.09 mg/l and less than 0.05 mg/l respectively. The free ammonia and total Kjeldahl nitrogen maximum concentrations were less than 0.1 mg/l and 0.70 mg/l, respectively. The quality of this melt water is better than can be expected from tertiary treatment.

This exceptional water quality in the ponded water is a result of the previous mentioned phenomena and dilution from the natural snow. When natural snow melts in the spring, the particulate matter that was in the snow remains on the ground with the melt water running off or percolating into the soil. This principle should remain with our manmade snow, with the solids and insoluble compounds remaining on the soil in the spring with the cleaner water running off. Also, the natural snow in the area would provide dilution for the runoff from our manmade snow before it reaches the rivers and streams. One of the major benefits of this type of system is that it makes use of every thaw, spring or winter, and maximizes its dilution during the melt period, minimizing environmental impact.

No sampling of the actual runoff was undertaken from the site due to the lack of a perimeter ditch or collector system.

Bacterial Parameters

In describing the bacterial concentrations in the lagoon wastewater and those in the snow, results are expressed in logarithms because of the nature of the data. For comparison with chemical data, a reduction of 1 log.

Table 6. Chemical results of ponded water on the experimental snow field following spring melt.

Date		BOD_5 (mg/l)	pH	Chloride as Cl	Turbidity in Formazin U.	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel	Nitrogens Nitrite	Nitrogens Nitrate
April 6, 1982											
Blue Mt. Resort		3.2	8.01	1.5		0.090	0.006	0.020	0.63	L0.001	L0.01
Blue Mt. Resort		2.4	7.94	1.5		0.090	0.006	0.015	0.68	L0.001	L0.01
Sampling Stations											
(April 15/82)	#1	1.6	8.29	5.0	0.60	L0.05	L0.05	L0.1	0.40	L0.01	L0.1
	#2	1.6	8.21	4.5	0.60	L0.05	L0.05	L0.1	0.40	L0.01	L0.1
	#3	2.0	8.25	3.5	0.80	L0.05	L0.05	L0.1	0.45	L0.01	L0.1
	#4	2.4	8.19	2.0	2.5	L0.05	L0.05	L0.1	0.40	L0.01	L0.1
	#5	3.6	7.89	6.5	2.0	0.08	L0.05	L0.1	0.65	L0.01	L0.1
	#6	2.4	8.12	8.0	1.3	L0.05	L0.05	L0.1	0.70	L0.01	L0.1
	#7	2.0	8.35	13.5	3.6	L0.05	L0.05	L0.1	0.45	L0.01	L0.1

equals a 90% reduction in the bacterial levels, whereas a 2 log. reduction corresponds to a 99% reduction and a 3 log. reduction to 99.9%, etc.

Results of the comparison demonstrating the effect of enclosing the aerosol sampling unit in a box are shown in Table 7. From this data, it was concluded that the box enclosed sampling unit functioned equally well as those that were free-standing.

From table 8, average log. reductions in total coliforms, fecal coliforms, fecal streptococci and Pseudomonas aeruginosa were 3.6, 3.6, 0.9 and 1.9 respectively. The coliform organisms which are comprised mainly of Escherichia coli and Klebsiella species were most susceptible to the temperature and relative humidity changes. In contrast, the fecal streptococcal group demonstrated a significantly greater resistance to environmental stresses than the coliform bacteria. This was similar to that reported by Cohen and Shuval, 1973 and McFeters et. al, 1974, concerning bacterial survival in aquatic environments. The reduction in the bacterial pathogen P. aeruginosa, however was significant as the organism was undetectable in the newly produced snow. This result might be expected as it has been reported that the organism is unable to survive at temperatures less than 4°C.

Results of run 3, which represented the first cycling of lagoon wastewater through the atomizing reservoir appear similar to the previous runs for the four bacterial parameters. Log. reductions of 3.2, 5.3, 0.4 and 2.4 were observed for total coliforms, fecal coliforms, fecal streptococci and P. aeruginosa respectively. Results of run 6, which also included cycling the wastewater once through the atomizing device were similar in bacterial reductions

for all parameters to the previously atomized run 3. The relative humidity during both runs was also similar at 62.8 and 65.1% respectively. The air temperature difference of -6.5°C between runs appeared to have a negligible effect on the bacterial survival.

Bacterial levels determined in the snow produced from runs 1 through 7 after five days exposure to ambient weather conditions were reduced to concentrations slightly higher than those of the upwind control snow (Table A4). Fecal streptococci were the exception as levels in the snow remained greater than 600 per 100 ml of snowmelt.

Based on the temperature and the relative humidity during runs 8 through 13, grouping of data from runs 8, 9 and 10 and 11, 12 and 13 were made. In the former group, coliform and fecal coliform log. reductions averaged 5.1 and 3.8 respectively at temperatures of -9.0°C and a relative humidity of 63.9%. In the latter group, coliform and fecal coliform log reductions averaged 3.8 and 2.6 respectively, at the same temperature, with a relative humidity of 80.2%. Based on these results, the survival of total coliforms and fecal coliforms is enhanced by an increase in relative humidity, whereas fecal streptococci appear insensitive to the increased humidity. As in the previous runs, the log. reduction in fecal streptococci was less than one. The log. reduction in the concentration of *Pseudomonas aeruginosa* also remained consistent at 1.7.

In addition to a temperature drop of 4°C (-8°C to -12°C) and cycling the wastewater twice through the atomizer during run 19, total coliform die-off resulted in only 1.7 log. reduction which was well below the average log. reduction of 3.7. Bacterial reductions for the other parameters were similar to the mean die-off values. From these data, it appears that the cycling of the lagoon wastewater through the atomizer had little effect on bacterial survival.

Table 7. A comparison of results of bacterial aerosol levels obtained with impactor units in an insulated box and without a box, adjacent to an aeration tank of an activiated sludge system.

Numbers of bacteria per plate on each stage of impactor unit.

Stage Number	Run 1 A-1	Run 1 B-1	Run 2 A-2	Run 2 B-2	Run 3 A-3	Run 3 B-3	Run 4 A-4	Run 4 B-4	Run 5 A-5	Run 5 B-5
1	31	24	9	28	37	34	31	34	18	18
2	13	18	10	11	20	3	7	11	9	14
3	21	31	13	15	19	15	21	16	19	18
4	18	15	11	9	8	8	18	13	11	10
5	1	1	5	3	7	4	2	2	2	0
6	1	0	0	1	2	3	0	2	1	2
Total	85	89	48	67	93	67	79	78	60	62

A - free standing

B - in box

Table 8. Results of bacterial reductions in comparing concentrations in the snow to levels in the lagoon wastewater expressed as log. reduction.

Run	Log Reduction Total Coliforms	Fecal Coliforms	Fecal Streptococci	*Pseudomonas aeruginosa*	Bacterial Aerosol levels (no. of bacteria per m³)	Air Temperature (in °C)	% Relative Humidity
1	6.4	5.5	2.1	2.5	2718.8	-2.0	N.A.
2	3.7	5.3	0.8	1.4	2931.3	-4.0	54.2
3	3.2	5.3	0.4	2.4	3767.2	-6.0	62.8
4	6.0	5.7	1.6	2.5	1536.9	-10.5	67.2
5	3.7	3.9	0.6	2.9	N.A.	-8.5	63.1
6	3.9	4.5	0.6	3.0	216.3	-12.5	65.1
7	2.4	1.8	0.5	2.3	2857.5	-11.5	76.3
8	4.6	3.2	0.6	2.6	1768.4	-9.5	67.1
9	6.9	5.1	0.8	1.6	1241.7	-8.5	65.2
10	3.9	3.0	0.5	1.3	1198.5	-9.0	63.9
11	3.8	3.1	0.5	1.3	1333.3	-9.0	79.2
12	3.9	2.1	0.3	1.3	590.3	-9.0	79.2
13	4.0	2.5	0.6	2.1	668.7	-9.0	82.1
14	4.6	3.1	1.5	2.0	2589.1	-6.0	68.2
15	3.8	2.7	0.9	2.0	4231.6	-6.0	61.2
16	3.7	2.7	0.7	1.9	2385.5	-7.0	71.0
17	4.1	3.4	1.0	1.5	2055.9	-7.0	67.0
18	3.0	3.7	0.3	2.9	3992.3	-8.0	67.0
19	1.7	3.0	0.2	2.8	2611.9	-12.0	67.0
20	N.A.	4.2	0.4	2.8	2664.1	-12.0	67.0
21	7.1	5.7	2.4	2.9	486.0	-7.0	60.0
22	4.1	5.7	0.9	2.0	708.6	-6.0	60.0
23	3.7	4.1	0.8	3.0	4171.7	-6.0	60.0
24	2.8	3.1	0.6	2.0	3136.0	-6.0	60.0
25	N.A.	N.A.	N.A.	N.A.	N.A.	--	--
26	2.8	2.6	0.8	3.2	2002.5	-5.0	60.0
27	3.5	3.0	4.6	2.7	2569.9	-5.0	67.8
28	N.A.	5.8	1.2	2.8	4198.4	-5.0	67.1
29	1.4	2.6	0.1	1.4	1680.6	-4.0	67.1
30	1.4	2.7	0.3	0.8	241.7	-2.5	67.1
31	1.8	2.8	0.3	0.9	1717.5	-2.0	64.6
32	*1.9	2.8	0.5	2.8	1786.2	-2.0	65.2
33	3.0	3.1	0.5	0	333.3	-6.0	75.0
34	1.3	2.1	0.5	0	146.3	-5.0	75.0
35	2.1	3.6	1.2	0	67.4	-1.0	75.0
Mean Log Reduction	3.6	3.6	0.9	1.9			
n =	32	34	34	34			
St.D.	1.5	1.2	0.83	0.9			
Mean Log Reduction "Cycled"	3.3	4.2	1.5	2.6			
n = 5	7	7	7				
St.D.	0.9	1.1	1.2	0.5			

N.A. - Not Available
*Run was shortened to 10 minutes

In comparison to the previous runs, the rate of wastewater utilization in run 20 having been increased 10-fold to 11.4 l/s, had a negligible effect as results again were similar to those of previous runs.

From Table 9, the effect of cycling wastewater through the atomizing reservoir at various flow rates and at a constant air and water pressure, can be observed. The changes in the four bacterial indicators between cycled and non-cycled wastewater did not appear significant regardless of the flow rate used. Although bacterial changes did not occur within the atomizing reservoir, changes could be still anticipated when the cycled wastewater was actually used to make snow based on the stress that the bacteria have incurred. The potential for this additional reduction was assessed in runs 3, 6, 17, 19, 20, 27 and 28. However, based on the mean reductions in bacterial concentrations in snow produced directly from wastewater, cycled once or cycled twice, differences could not be observed.

In Table 10, reductions in bacterial concentrations in the snow pile which was made independent of standard snow production runs, are displayed. Within a seven day period, coliforms were detected at concentrations of less than 160 per 100 ml of snow melt. The bottom 10 centimeters of the snow pile appeared to provide the most favorable environment for the organisms as they remained detectable at the 49th day of sampling. Fecal coliforms however, were not recovered after 24 hours and remained undetectable throughout the snow pile and sampling period. As was observed during snow production, fecal streptococci survival was much greater than coliform bacteria. The die-off of the fecal streptococci occurred to some degree;

Table 9. Survival Coliform, Fecal Coliform, Fecal Streptococcus and Pseudomonas aeruginosa following cycling of wastewater through atomizer.

Test No.	Air/Water Pressure kPa	Flow Rate (lbs)	Total Coliform $\times 10^6$	Fecal Coliform $\times 10^5$	Fecal Streptococci $\times 10^5$	Pseudomonas aeruginosa $\times 10^2$	
			No. of Bacteria $\times 10^{(n)}$ per 100 ml				
1	552	6.1	6.2	3.6	3.8	4.0	L
	1379		2.5	4.4	3.9	4.0	C
2	552	4.5	2.1	2.8	2.8	2.6	L
	1379		2.3	3.2	3.1	5.0	C
3	552	2.7	0.7	2.5	3.9	2.8	L
	1379		1.6	1.8	3.6	2.9	C
4	552	2.7	0.8	2.4	2.6	5.0	L
	1379		1.9	2.6	3.8	7.2	C
5	552	4.1	1.5	2.6	5.1	4.9	L
	1379		1.7	2.7	6.3	5.5	C
6	552	4.1	2.1	3.2	4.8	4.7	L
	1379		1.3	2.8	6.0	5.8	C
7	552	4.1	7.7	3.3	5.2	6.4	L
	1379		1.4	2.0	3.6	5.1	C
8	552	4.1	0.6	2.7	3.6	6.2	L
	1379		1.0	3.2	4.9	5.6	C

L - lagoon wastewater
C - cycled

Table 10. Changes in concentrations of bacteria in the snow pile with time.

Time (Days)		Total Coliform	Fecal Coliform	Fecal Streptococci	*Pseudomonas aeruginosa*	*Clostridium perfringens*
		(Expressed as numbers of bacteria per 100 ml of snowmelt)				
0		1060	57	105,500	L4	N.D.
1	Top 10 cm	575	575	61,000	L4	N.D.
	Middle 10 cm	N.D.	N.D.	N.D.	N.D.	
	Bottom 10 cm	N.D.	N.D.	N.D.	N.D.	
7	Top 10 cm	L10	L10	G21,000	L4	N.D.
	Middle 10 cm	A30	L10	G360,000	L4	N.D.
	Bottom 10 cm	160	L10	G18,600	L4	N.D.
10	Top 10 cm	A20	L4	1,400	L4	N.D.
	Middle 10 cm	A10	L4	10,800	L4	N.D.
	Bottom 10 cm	C30	L4	10,200	L4	N.D.
29	Top 10 cm	4.5	L4	455	L4	N.D.
	Middle 10 cm	L4	L4	36,500	L4	N.D.
	Bottom 10 cm	36	L4	12,000	L4	N.D.
49	Top 10 cm	L4	L4	A10	L4	2,500
	Middle 10 cm	L4	L4	3,500	L4	6,700
	Bottom 10 cm	230	L4	500	L4	112

N.D. - Not Done

however, the organisms were easily detectable at the end of the sampling period. Pseudomonas aeruginosa did not appear to survive initial snow production, and therefore, remained undetectable in the snow pile.

During the last snow pile sampling period (49th day) an additional bacterial parameter, Clostridium perfringens was added. The organism being found in sewage is known to be resistant to environmental stress such as temperature and pH (Buchanan and Gibbons, 1974). Its survival during snow production was demonstrated in the results of runs 33, and 34, and 35 (Table 9). Levels were also considerably higher in the snow pile. It is apparent that this bacterium is capable of a lengthy survival period in the snow. Concentrations in the newly produced snow ranged from 7,500 to 10,700 per 100 ml, while after 49 days concentrations in the snow pile ranged from 112 to 6700 per 100 ml of snow melt. The Clostridium perfringens and fecal streptococci have a common feature in that they are both gram positive bacteria. Their relatively thick cell wall (200-800A) which is known to contribute to their resistence in addition to endogenous spore of C. perfringens (Bisson and Cabelli, 1980) may be the reason for their survival during snow production as well as during the following exposure period of the snow accumulation.

From figure 5, the bacteriological results obtained from the grid sampling in the snow accumulation area after 19 days' exposure demonstrate a significant reduction in the pollution indicator organisms and the pathogen Pseudomonas aeruginosa. The levels of bacteria beyond the 20 meter point are identical to the levels of bacteria in the upwind control station. The resistance of fecal streptococci was again demonstrated from the data in the figure as its survival was greater than any of the other bacteria in this evaluation.

Figure 6. Bacteria surviving in snow produced from wastewater nineteen days previous.

Gun 4

	95m	55m	27m	24m	6m	Gun 4	1.8 m	Control 18 m
	TC L4	TC L4	TC L4	TC L4	TC 32		TC L4	TC L4
	FC L4	FC L4	FC L4	FC L4	FC L4		FC L4	FC L4
	FS L4	FS L4	FS L10	FS 8000	FS 430		FS L10	FS 160
	Pa L4	Pa L4	Pa L4	Pa L4	Pa L4		Pa L4	Pa L4

Downwind

Gun 3

	146 m	131 m	95 m	55 m	27 m	24 m	6m
	TC L4	TC L4	TC L4	TC L4	TC L4	TC L4	TC L4
	FC L4	FC L4	FC L4	FC L4	FC L4	FC L4	FC L4
	FS L4	FS L4	FS L4	FS L4	FS 40	FS 90	FS 520
	Pa L4	Pa L4	Pa L4	Pa L4	Pa L4	Pa L4	Pa L4

Gun 2

Gun 1

	95m	55m	27m	24m	6m	Gun 1	1.8 m	Control 6 m
	TC L4	TC L4	TC L4	TC L4	TC 32		TC L4	TC L4
	FC L4	FC L4	FC L4	FC L4	FC L4		FC L4	FC L4
	FS L4	FS L4	FS L10	FS 250	FS 130		FS 700	FS 8
	Pa L4	Pa L4		Pa L4	Pa L4		Pa L4	Pa L4

TC = Total coliforms per 100 ml of snow melt
FC = Fecal coliforms per 100 m of snow melt
FS = Fecal streptococci per 100 ml of snow melt
Pa = *Pseudomonas aeruginosa* per 100 ml of snow melt

Of significance were the bacterial log. reductions of run 21 since all four parameters decreased in concentrations in the snow melt below the averages determined (see Table 6). This resulted during snow production at a flow rate of 4.5 litres per second, at a temperature of -6.0°C and a relative humidity of 60%. The relative humidity was second lowest recorded in the study and may have contributed to the increased die-off of bacteria.

In contrast, snow produced during run 31 at -2.0°C, at a relative humidity of 64.7% and a flow rate of 3.0 l/s was wet or slushy in nature. Bacterial reductions were minimal for all parameters. The survival of Pseudomonas aeruginosa was notable at a level of 64 per 100 ml of snow melt as it had not been recovered in previous runs. From the detectable levels of bacteria in the snow following snow production during temperatures above - 5.0°C, it appears that this aspect of treatment is unsuitable.

In run 35, although a minimal flow rate of 0.3 l/s was utilized, bacterial reductions remained typical of the average reduction. An additional bacterial parameter, Clostridium perfringens was added to the set of analyses on sample runs 33, 34 and 35. Concentrations in the wastewater and the snow melt samples are shown in table 11.

Bacterial Aerosolization

The production of a microbial aerosol is inherent in the making of snow because as a water particle is accelerated at high speed through a snow gun nozzle to suddenly be cooled to form a snow crystal, biological particles (bacteria virus, etc.) are projected into the atmosphere. A percentage of these organisms in any unit volume of wastewater are contained in the newly formed

Table 11. Bacterial concentrations expressed as numbers per 100 ml of snow melt.

Run Number/ Site		Total Coliforms	Fecal Coliforms	Fecal Streptococci	*Pseudomonas aeruginosa*	*Clostridium perfringens*
33	Sewage	1.4×10^6	4.4×10^4	9.4×10^4	L4	6.1×10^3
	Snow	1.3×10^3	3.2×10^1	2.8×10^4	L4	10.7×10^3
34	Sewage	1.3×10^6	3.3×10^4	10.5×10^4	L4	10.7×10^3
	Snow	6.6×10^4	2.68×10^2	3.1×10^4	L4	8.3×10^3
35	Sewage	8.7×10^5	4.1×10^4	10×10^4	L4	7.6×10^3
	Snow	6.0×10^3	8.0	7.0×10^3	L4	7.5×10^3

snow crystal, while the remainder are propelled into the air. Organisms in the former circumstance soon settle as part of the snow crystal. The other portion of the bacteria, etc. become aerosolized, where they are adsorbed to dust and snow particles. As mentioned previously, sampling of the air in this study to ascertain the bacteriological component in the aerosol was accomplished by initially determining the levels of heterotrophic bacteria (recovered in aerosol sampler) capable of survival under environmental conditions during the making of snow.

From a 70 meter location downwind, levels of aerobic heterotrophic bacteria recovered in the aerosol ranged from 333.3 to 4231.6 organisms per cubic meter of air with an average concentration over 30 runs of 1640.2 (Geometric Mean) per cubic meter. Runs 19, 30 and 34 were used to determine the facultative and anaerobic component of the heterotrophic bacterial population in the air. A range from 146.3 to 2611.9 bacteria per cubic meter was detected. It was expected that the recoverability of anaerobic bacteria was somewhat dubious as the sampling technique was not ideal for this purpose. The air passing over the agar plates in the impactor sampling unit would probably adversely affect the survival of any strictly anaerobic bacteria.

Results of the 130 meter downwind sampling exhibited a bacterial concentration in the aerosol of 597.3 (average) per cubic meter as compared to 3653.9 (average) per cubic meter at the 70 meter location. This six-fold reduction in approximately twice the distance from the aerosol source demonstrates a significant drop in numbers of viable cells occuring during the winter climatic conditions. In a comparison study reported by Johnson et al, 1978 conducted during spray irrigation of municipal sewage, the

bacterial reduction in the aerosol expressed as a standard plate count concentration from 20 meters to 200 meters was only 2.9. It should also be noted that the standard plate count results in this study of 10^3 bacteria per cubic meter were similar to those reported in the literature from secondary waste treatment facilities. (Fedorak and Westlake, 1980 and Glaser and Ledbetter, 1967).

Aerosolization of Pathogens

Table 12 provides results for the standard pollution indicator bacteria and pathogen levels per cubic meter of aerosol. The concentration of the pollution indicator bacteria are somewhat higher than those reported by Johnson et al, 1978, Fedorak and Westlake, 1980 and Hickey and Reist, 1975 however, the lagoon wastewater being aerosolized in this study contained levels of coliform, fecal coliform and fecal streptococci bacteria 1000-fold higher than those in the Johnson study.

Since the reliability of the pollution indicator bacteria have been criticized as to their value when assessing aerosol contamination, detection of pathogenic bacteria such as *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Salmonella sp.*, *Staphylococcus aureus*, and *Clostridium perfringens* were included. As can be observed from the table, their recovery appeared to be below the limit of the detection technique in most cases. Of the pathogenic bacteria recovered, all were confirmed biochemically as to their genus and species. Since the percent recovery of most of the above-mentioned pathogenic organisms from nutrient agar plates was greater than 80% and that the levels of bacteria recovered on the plates in impactor were similar to those reported by others, it was concluded that the levels of pathogens remaining viable in in aerosols samples must have been low (perhaps less than 1 per cubic meter of air).

Table 12. Aerosol concentrations of standard pollution indicator and bacterial concentrations expressed as numbers of cells per cubic meter of air.

Run Number	Standard Plate Count	Total Coliforms	Fecal Coliforms	Fecal Streptococci	*Pseudomonas aeruginosa*	*Salmonella* sp.	*Clostridium perfringens*	*Staphylococcus aureus*	*Klebsiella pneumoniae*
1 A	35.6								
B	3718.8	10.2	63.6	2.5		0		0	
2 A	NA								
B	2931.3								
3 A	96.7								
B	3767.2								
4 A	6.4								
B	1536.9								
5 A	2.5								
B	NA								
6 A	0.0								
B	216.3								
7 A	0.0								
B	2857.5	27.2	33.1	40.7		0		30.5	
8 A	2.5								
B	1768.1	43.2	91.6	167.9	0				
9 A	2.5								
B	1241.7	17.8	78.9	142.5	0				
10A	7.6								
B	1198.5	38.2	112.0	81.4	0				
11A	0.0								
B	1333.3	33.1	53.4	71.2	0				

Run Number	Standard Plate Count	Total Coliforms	Fecal Coliforms	Fecal Streptococci	Pseudomonas aeruginosa	Salmonella sp.	Clostridium perfringens	Staphylococcus aureus	Klebsiella pneumoniae
12A	1.3								
B	590.3	33.1	33.1	40.7	0				
13A	5.2								
B	668.7	21.5	27.6	30.7	0				
14A	1.7								
B	2589.1								
15A	0.0								
B	4231.6								
16A	3.1								
B	2385.5								
17A	7.6								
B	2055.9	45.8	40.7	84.0	0	0	0		
18A	2.5								
B	3992.3								
19A*	0.0								
B	2611.9							0	
20A	2.5								
B	2664.1	56.0	2.5	169.0	0	0	0		
21A	5.0								
B	486.0	17.8	14.0	42.0	0	0	0		
22A									
B	708.6	35.6	35.6	38.2	0	0	0		
23A	3.8								
B	4171.7								

Run Number	Standard Plate Count	Total Coliforms	Fecal Coliforms	Fecal Streptococci	Pseudomonas aeruginosa	Salmonella sp.	Clostridium perfringens	Staphylococcus aureus	Klebsiella pneumoniae
24A	2.5								
B	3136.0								
27A	10.1								
B	2569.9	108.1	53.6	106.9	0	0	0	0	3.8
28A	10.1								
B	4198.4	43.2	28.6	58.5	0	0	0		
29A	12.7								
B	1680.6	89.0	54.7	194.6	0				
30A*	0.0								
B	241.7							3.8	
31A	5.3								
B	1717.5	53.4	12.7	28.0					3.8
32A	11.4								
B	1786.2	26.7	22.9	30.5					
33A	NA								
B	333.3								
34A*	NA								
B	146.3								
35A	NA								
B	67.4								

Geometric Mean of Aerobic Runs = 1640.2 n = 30
Geometric Mean of Anaerobic Runs = 452.0 n = 30
Geometric Mean of Atomized Runs = 1907.4 n = 7
NA - Not Available
*Anaerobic Run
A - Upwind Results
B - Downwind Result

APPENDIX A

DATA

Table A1 Chemical results during the manufacturing of snow from sewage

DATE			BOD5 (mg/l)	Susp. Solids	chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Fe	Na	SO_4
RUN 1																		
LAGOON CONTENTS	JAN 6		45	35.2	62	7.52	3.40	2.45	23.5	27.5	0.01	<0.1	81	24.6	304	1.32	60	33.5
SNOW SAMPLED (BACKGROUND)	JAN 7		12	248.6	10.5	8.51	1.08	0.20	0.8	5.85	0.02	0.5	13	3.6	47	15.2	8.3	9.0
SNOW UPWIND			4.6	83.1	4.0	8.78	0.07	<0.05	0.1	1.0	.01	0.6	18	5	66	.63	2.1	9.0
SNOW 35 metres D/W			2.0	29.9	<.5	7.94	<.05	<.05	<.1	0.5	<.01	0.3	1.5	0.4	5.0	0.45	0.1	1.5
SNOW 70 metres D/W			1.8	20.8	<.5	7.75	<.05	<.05	0.1	0.4	<.01	0.4	1.5	0.2	5.0	0.50	0.1	1.5
RUN 2																		
LAGOON CONTENTS	JAN 7		44	31.5	62.5	7.54	3.2	2.4	23	26.5	<.01	<.1	80	24.8	302	0.88	51.5	49.5
SNOW MADE	JAN 7		36	54.3	67	8.99	3.65	1.5	17.6	27.5	.08	0.9	62.5	25.8	26.3	1.1	55	52
SNOW ABOVE SAMPLED 2 hrs. LATER			38	65.4	65	9.24	3.3	1.3	14.6	23.5	.04	1.0	51	25	231	1.38	53	47
RUN 3																		
1 X ATOMIZED			50	42.1	61.5	7.95	3.25	2.15	22.5	27.3	<.01	<.1	79.5	24.6	300	2.95	47	48
SNOW FROM ABOVE			43	77.8	65.5	9.2	3.35	1.35	16.3	26	.07	.9	52	25.6	235	2.76	53.5	49
RUN 4																		
LAGOON CONTENTS	JAN 14		36	27.5	152	7.63	5.40	3.60	23.5	34.3	.02	2.1	92	27.8	345	0.54	106	53.5
SNOW B, GUN 3			19	15	52.5	9.41	1.64	0.65	7.5	10.5	.03	.4	28.5	8.6	101	0.24	73.5	19
SNOW B, GUN 4			52	57.9	118	9.03	4.15	1.65	18.3	25.8	.15	.2	59	21.6	236	0.75	86	41.5
SNOW A, CONTROL			1.2	2.7	0.5	5.08	<.05	<.05	<.1	.15	.02	0.4	0.5	0.2	2.0	0.19	0.4	1.0

Table A1 - Continued

DATE			BOD5 (mg/l)	Susp. Solids	chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F A	Nitrogens Kjel	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Fe	Na	SO_4
RUN 5																		
LAGOON CONTENTS			45	34.3	105	7.56	5.30	3.30	23.0	35.5	.01	<.1	82.0	25.0	308	1.68	80.0	56.0
SNOW B - GUN 1			72	147.0	100	9.42	4.65	0.70	18.7	33.0	.08	0.3	46.5	22.4	209	2.15	77.0	52.0
SNOW B - GUN 2			76	145.8	10	9.26	5.40	1.05	21.5	40.0	0.09	0.3	56.0	25.6	245	2.20	77.0	57.0
SNOW A - CONTROL			1.4	19.0	1.5	8.12	<.05	<.05	0.1	0.25	<.01	0.4	1.0	0.2	3	0.41	0.8	1.5
RUN 6																		
RAW WATER	JAN 14		54	35.3	92.5	7.55	6.00	3.95	27.5	40.3	0.01	<.1	78.5	24.2	296	0.44	74	57.5
SNOW B GUN 1			90	153.6	97.5	9.46	6.00	0.75	19.5	39.5	0.05	0.6	55.5	24.2	238	0.75	77	56.0
SNOW B GUN 2			92	114.0	96.5	9.41	5.60	0.70	20.0	40.8	0.06	0.6	56.5	24.2	241	0.55	77	55.5
SNOW A - CONTROL			2.0	14.2	1.5	8.11	<.05	<.05	<.1	0.15	<.01	0.4	2	0.6	7	0.86	0.7	1.0
RUN 7	JAN 14																	
RAW WATER			52	34.3	92.5	7.34	6.00	3.95	28.5	40.5	0.01	<.1	78.5	23.8	294	.45	74	57.0
SNOW B GUN 3			82	112.3	94.0	9.38	5.6	0.70	19.3	39.8	0.07	0.5	58	23.6	242	0.55	75	54
SNOW B GUN 4			84	105.0	94.0	9.51	5.45	0.70	18.7	38.8	0.07	0.6	55.5	23.4	235	0.55	73	53.5
SNOW A - CONTROL			1.4	9.7	12	8.86	0.46	0.20	1.5	2.4	0.01	0.4	8	3	32	.09	8.7	6.0
RUN 8																		
RAW WATER	JAN 19		86	25.5	178	7.68	7.4	6.05	36	50	<.01	<.1	117	39.8	456	–	135	66
SNOW GUN 1			92	232.2	210	9.42	7.15	1.45	40.5	50.5	0.01	<.1	40	39	261	–	152	61
GUN 1			92	239	202	9.19	7.35	2.15	40	51.5	0.01	<.1	52.5	40.4	298	–	152	61.5
CONTROL			3.2	4.8	2.5	8.40	0.14	0.05	0.7	1.50	0.01	0.4	2	1.2	10	–	2.1	5

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Table A1 - Continued

DATE			BOD5 (mg/l)	Susp. Solids	chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F A	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Fe	Na	SO_4
RUN 9	JAN 19																	
RAW WATER			88	29.6	238	7.67	9.00	7.60	37	50.5	<.01	<.1	120	40.4	466	-	168	67
SNOWGUN 1			90	214.3	210	9.36	7.05	1.55	41	51	.01	<.1	40	40.4	266	-	152	62.5
SNOW			90	216.3	208	9.35	6.95	1.50	42.5	50	.01	<.1	37.5	41.2	263	-	151	66.5
CONTROL			2.8	5.8	210	8.26	0.09	<.05	0.6	1.2	<.01	0.3	1.5	0.6	60	-	1.3	4
RUN 10	JAN 19																	
RAW WATER			84	29.5	230	7.66	9.40	7.95	41	53	<.01	<.1	124	42.8	486	-	165	66
SNOW GUN 2			106	273.6	238	9.39	8.95	1.70	45	60	.01	<.1	+	44	+	-	173	60.5
SNOW GUN 2			104	246.2	240	9.06	8.90	2.50	42	58.8	.01	<.1	+	43.6	+	-	176	60.5
CONTROL			2.4	3.8	2.5	8.27	0.10	<.05	0.7	1.2	<.01	0.3	2	1.0	9	-	1.8	4.0
RUN 11	JAN 19																	
RAW WATER			92	28.6 / 30.7	225	7.61 / 7.93	9.80 / 9.2	8.0 / 7.35	42.5 / 39.5	54 / 53	<.01 / .02	<.1 / <.1	126 / 134	42.8	491	-	167	68.0
SNOW GUN 2			100	227.2	245	9.16	8.5	2.1	43.5	57.5	.02	<.1	53.5	43.2	312	-	178	60.5
SNOW GUN 2			104	245.3	242	9.32	8.3	1.85	43	60	.02	<.1	46.5	43.6	296	-	174	60.5
CONTROL			2.8	5.8	3.5	8.05	.19	.05	1.0	1.7	<.01	0.5	2	.8	8	-	2.6	5
RUN 12	JAN 19																	
RAW WATER			100	275	235	7.64	9.4	8.05	41.5	53	<.01	<.1	126	42.8	491	-	167	63
SNOW GUN 2			96	233.1	245	9.26	8.25	1.95	40.0	61	.02	<.1	50.5	44.0	308	-	174	60
GUN 2			100	234.3	240	9.26	8.7	2.05	39.0	60	.02	<.1	48.5	42.4	296	-	174	59
CONTROL A			2	6.2	1.5	8.00	<.05	<.05	0.3	0.7	<.01	0.3	1.0	0.4	40	-	0.6	2.5

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Table A1 - Continued

DATE		BOD5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol.	Nitrogens F. A	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO_4
RUN 13	JAN 19															
RAW WATER		94	36.2	242	7.69	9.5	7.8	41.5	53	<.01	<.1	128	40	485	175	63
SNOW GUN 2		37	39.4	89.5	9.61	3.0	.85	10.5	15.5	.03	0.3	34.5	15.6	151	61.5	25.5
GUN 2		62	108.5	160	9.55	5.2	.75	11.8	27.5	.02	0.3	37.5	27.2	206	112	43
CONTROL		2.8	10.3	3.0	8.36	.22	.05	0.7	1.3	<.01	0.3	2.0	0.4	7	1.8	4.5
RUN 14	JAN 20															
RAW WATER		102	30.9	238	7.6	9.2	7.85	40.5	51	<.01	<.1	128	40	485	167	60
SNOW GUN 1		56	20.6	145	9.4	4.8	1.15	22.5	29	.02	0.5	37.5	24	193	105	38.5
GUN 2		86	108.2	208	8.98	7.6	2.2	30.5	43.8	.02	0.5	67	35.8	315	146	55
CONTROL		1.6	15.2	1.5	8.61	0.05	<.05	0.2	0.5	<.01	0.2	2	1	9	0.7	2.5
RUN 15	JAN 20															
RAW WATER		98	31.7	232	7.7	9.2	7.85	41.5	49.5	<.01	<.1	127	41	436	169	62
SNOW		98	151.7	248	9.02	8.55	2.00	39.5	57.5	0.02	<.1	64	40.4	326	173	56.5
CONTROL		2	13.5	1.5	8.28	.06	<.05	0.3	0.7	<.01	0.2	2	0.4	7	0.3	0.3
RUN 16	JAN 20															
RAW WATER		104	31.2	232	7.7	9.3	7.95	40.5	50	<.01	<.1	126	41	434	163	61
SNOWGUN 1		98	158.8	250	9.16	8.8	1.85	39.0	56.3	0.02	<.1	55	42	311	180	55
GUN 2		102	178.4	250	9.24	9.4	1.65	41.0	56	0.02	<.1	51.5	42	302	178	55
CONTROL		1.6	9.8	1.5	8.26	0.38	<.05	0.5	5.8	<.01	0.4	1.5	0.2	5.0	0.8	2.5

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Table A1 - Continued

DATE			BOD_5 (mg/l)	Susp. Solids	chloride	pH	Phosphorus Total	Phosphorus Sol.	Nitrogens F. A	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO_4
RUN 17	JAN 26																
RAW WATER			36	38.3	110	7.60	6.3	3.35	19	27.5	<.01	<.1	83.5	25.8	315	80	36
SNOW GUN 4			76	110	132	8.70	5.8	2.65	20.5	25	0.12	0.9	61.5	25.6	259	96	46
CONTROL A			3	16.8	2.5	8.25	0.12	.05	0.4	0.9	<.01	0.4	3.5	0.8	12	2.1	4.0
RUN 18	JAN 26																
RAW WATER			40	43.6	108	7.69	5.9	3.4	21.5	25.5	<.01	<.1	83.5	26	316	30	36
SNOW GUN 4			72	184.3	128	9.39	6	1.5	19.5	27	.09	0.8	48	25.3	226	86	39.5
CONTROL A			3.0	20.6	1.5	8.6	.06	<.05	0.1	0.45	<.01	<.1	1.5	0.4	5	.8	1.5
RUN 19																	
RAW ATOMIZED TWICE			36	39.9	110	7.6	6.2	3.5	19.9	27	<.01	<.1	83.5	25.8	315	79	36.5
SNOW			68	166.9	125	9.06	6.4	1.9	19.0	29	.11	0.9	56.0	26.4	249	85	34.0
CONTROL			2.2	42.5	1.5	8.24	.009	<0.05	0.1	0.55	<0.01	<0.1	2.0	0.2	6	0.9	1.5
RUN 20	JAN 26																
RAW ATOMIZED TWICE			36	41.1	101	7.6	6.1	3.45	20	26.5	<0.01	<0.1	84.5	25.6	317	80	36
SNOW GUNS 4			66	179	12.0	9.39	6.2	1.5	19	27.5	0.12	0.8	45.5	25.2	218	33	37
CONTROL A			3.4	41.2	1.0	8.2	.08	<.05	0.1	.45	<.01	<.1	2	0.2	6	0.7	1.5

Table A1 - Continued

DATE			BOD_5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F. A	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO_4
RUN 21	JAN 27																
RAW WATER			42	27.7	105	7.56	5.9	3.95	17.1	23.5	<.01	<.1	82.5	25	309	74	33.5
SNOW GUN 2			20.4	20.5	32.5	9.11	1.58	1	4.5	6.7	.02	0.6	24	8	93	21.8	14.5
SNOW GUN 4			61	143.6	108	9.29	5.4	1.8	16.9	23	.05	1.0	47.5	24.6	220	74	37
CONTROL A			2	12.3	1.5	7.67	.07	<.05	0.7	1.1	<.01	0.3	2.5	0.4	8	0.7	3.5
RUN 22	JAN 27																
RAW WATER			44	27.7	102	7.62	6.1	3.85	16.8	24	<.01	<.1	82.5	25.6	312	73	33.5
SNOW GUN 2			57	52.2	80	8.33	4.7	2.6	15.5	19.3	.05	.8	60.5	19.4	231	54	26.5
SNOW GUN 4			76	161.7	112	9.13	6.4	1.7	18.5	28.3	.07	1.1	57	27.2	255	76	38
CONTROL A			1.4	20.2	1	7.83	<.05	<.05	0.1	0.4	.01	<.1	1.5	0.4	5	0.3	1.5
RUN 23	JAN 27																
RAW WATER			50	38.7	82.5	7.69	5.4	3	23	29.5	<.01	<.1	77	24.6	294	64	32.5
SNOW GUN 2			68	130.2	90	9.07	5.9	1.7	17.7	31	.06	1.1	57.5	25	247	67	37.5
SNOW GUN 4			48	42.8	42.5	8.1	3.65	1.9	11.4	15.6	.04	.5	43	11.2	154	31	17.5
CONTROL A			2.4	23.5	2	7.91	0.12	<.05	0.7	1.15	<.01	.4	2.5	0.4	8	1.2	4
RUN 24	JAN 27																
RAW WATER			46	39.3	79	7.65	5.6	2.95	24	31	<.01	<.1	77	24.4	293	62	32.5
SNOW GUN 2			68	166.6	90	9.08	5.4	1.8	17.9	31	.06	1.2	60.5	26.6	261	68	39.[illegible]
SNOW GUN 4			65	134.6	85	9.10	5.9	1.65	17.3	32.5	.07	1.1	58	25.8	251	66	37
CONTROL A			3.0	19.2	3.5	7.91	0.18	0.18	0.6	1.2	.01	0.4	3.5	0.6	11	2.4	3.5

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Table A1 - Continued

DATE			BOD5 (mg/l)	Susp. solids	chloride	pH	Phosphorus Total	Phosphorus Sol.	Nitrogens F. A	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO4	
RUN 25	(RUN WAS STOPPED)																	
RUN 26	JAN 27																	
RAW WATER			47	41.1	72.5	7.74	5.4	2.7	28.5	34.5	<.01	<.1	76	24.2	290	58	33	
SNOW GUN 2			62	131.5	80	9.17	5.35	1.65	17.6	33.5	.07	1.1	53	24.8	235	60	37	
SNOW GUN 4			62	138.1	80	9.32	5.6	1.4	18.2	35.0	.08	1.1	51.5	25	232	60	37	
CONTROL A			3.6	10.5	4.0	8.27	0.2	0.1	0.7	1.4	<.01	0.5	3.5	0.6	11	2.7	4.0	
RUN 27	JAN 29																	
RAW WATER			-	42.3	328	7.73	5.2	2.9	19.5	27.5	.01	<.1	83	26.8	318	198	35.5	
SNOW GUN 4			-	47.5	252	9.46	3.6	1.1	12.4	16.5	.06	0.9	47.5	19	197	150	26	
CONTROL A			-	31.8	11.5	8.15	0.49	0.30	1.0	1.8	.02	1.2	7	2.2	27	7.9	10.5	
RUN 28																		
RAW WATER	(SAMPLE LOST)		-															
SNOW GUN 4			-	64.2	318	9.31	4.8	2	17.7	23	.09	1.1	71	24.2	277	178	32.5	
CONTROL A			-	24.1	10.5	8.64	0.42	0.25	0.8	1.7	.01	0.9	8	1.6	27	7.2	8.5	
RUN 29																		
RAW WATER				25.6	72.5	7.85	4.3	2.35	23.5	30.5	0.12	<.1	72.5	24	280	58	32.5	
SNOW GUN 4				35.1	75	8.5	4.5	2.5	20	29.5	0.17	1.2	76.5	25.4	296	63	33.5	
CONTROL A				25.5	11.5	8.57	0.50	0.25	0.8	1.75	0.02	1.0	8	1.8	27	8	9	

Table A1 - Continued

DATE		BOD_{20}	BOD_5 (mg/l)	Susp Solids	chlorides	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A	Nitrogens Kjel	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO_4
RUN 30																	
RAW WATER				24.2	67.5	7.84	4.3	2.35	23.5	29.5	.09	<.1	72	23.3	278	56	32.5
SNOW GUN 4				34.6	72.5	8.26	4.6	2.5	21.5	23.5	.17	1.1	75	24.6	289	61	32
CONTROL A				32.3	10	8.45	.44	0.2	0.3	1.75	.02	1.0	8.0	1.6	27	6.3	9.0
RUN 31																	
RAW WATER				23.4	75	7.86	4.4	2.4	24.5	30.5	.15	<.1	72.5	24	280	53	32.5
SNOW GUN 4				37.1	77.5	8.44	4.5	2.4	22	28.5	.16	1.1	75.5	25.9	293	63.5	38
CONTROL A				30.6	5.5	8.28	.24	.10	0.5	1.15	.01	0.6	6.5	0.3	20	2.7	5.5
RUN 32																	
RAW WATER				28.3	110	7.82	4.5	2.5	24.5	31.0	.35	<.1	76	25.4	295	81	34
SNOW GUN 4				70.1	82.5	9.21	4.5	1.85	19.5	28.5	.16	1.1	72.5	24.8	283	68	38
CONTROL A				37.1	11.5	8.05	.47	.25	1.3	2.8	.02	1.4	10.5	2.0	34	80	170
RUN 33	MAR 9																
RAW WATER		335	122	14.3	82.5	7.89	7.20	5.90	52.5	56.5	0.01	<0.1	71.5	25.0	232	81.0	44.0
SNOW GUN 2		140	104	73.2	87.5	8.83	9.25	2.80	44.5	56.3	0.02	<0.1	56.0	24.8	242	89.0	46.5
CONTROL A			1.2	9.9	<0.5	7.33	<0.05	<0.05	0.1	0.20	<0.01	1.2	2.0	0.4	7	0.3	1.0
RUN 34	MAR 9																
RAW WATER		370	120	13.5	85.0	7.89	7.20	6.00	47.5	58.0	0.01	<0.1	72.0	25.2	284	80.0	44.0
SNOW GUN 2		140	100	42.1	90.0	8.36	7.10	4.75	33.0	56.0	0.01	<0.1	70.0	25.6	280	88.0	46.0
CONTROL A			1.6	11.5	<0.5	8.40	<0.05	<0.05	<0.1	0.20	<0.01	0.7	1.0	0.2	3	0.3	1.0

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Table Al - Continued

DATE	-	BOD_{20}	BOD_5 (mg/l)	Susp			Phosphorus		Nitrogens				Ca	Mg	Hardness	Na	SO_4	
				Solids	chloride	pH	Total	Sol	F. A	Kjel.	Nitrite	Nitrate						
RUN 35	MAR 9																	
RAW WATER		>365	120	13.1	85.0	7.91	7.10	5.95	55.0	56.5	0.01	<0.1	72.0	25.2	284	81.0	44.0	
SNOW GUN 2		110	78	27.4	62.5	3.33	5.60	4.00	34.0	41.0	0.01	<0.1	54.5	17.8	210	61.0	33.0	
CONTROL A			1.2	7.7	0.5	7.30	<0.05	<0.05	<0.1	0.25	<0.01	1.1	1.0	0.2	3	0.4	1.0	

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Table A2 Chemical results showing the effects of storage as snow

SNOW PILE			BOD_5 (mg/l)	Susp Solids	chloride	pH	Phosphorus Total	Phosphorus Sol.	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO_4
SNOW PILE (IMMEDIATELY)	JAN 19		93	234.2	242	9.51	8.15	1.10	26	35.8	.04	<.1	40	43.2	271	184	90
7 DAYS TOP	JAN 26		98	265.8	230	9.60	8.00	1.65	16.4	26	.03	<.1	37.5	37.2	247	152	615
MIDDLE			34	293.6	50.5	9.60	5.40	1.00	7.9	13	.01	<.1	35	10.8	132	34	18
BOTTOM			37	126.9	80.0	9.74	3.10	1.35	5.6	10	.01	<.1	24	17	130	56	275
10 DAY TOP	JAN 29		L.A.	226.1	238	9.83	7.8	1.1	9.8	18.5	.03	<.1	76.5	39.8	355	164	70
MIDDLE			L.A.	243.8	45.0	9.97	5.2	.65	5.7	10	.01	<.1	60	9.6	190	32	17
BOTTOM			L.A.	149.1	57.5	9.94	3.9	.80	4.6	8.5	.01	<.1	52	12.8	183	40	235
29 DAY TOP	FEB. 17		34	234.2	32.5	9.94	8.00	0.40	4.5	7.00	<0.01	<0.1	36.5	12.2	142	30.0	12.0
MIDDLE			96	115.0	232	9.57	6.50	1.75	5.9	15.5	0.03	<0.1	60.0	31.0	302	169	61.5
BOTTOM			22	223.8	60.0	9.86	4.90	0.85	3.1	7.8	0.02	<0.1	32.5	12.6	133	45.0	21.5
29 DAY TOP	FEB. 17		42	209.7	112	9.92	7.4	0.45	5.6	10.0	.01	<0.1	60.0	20.0	232	75.0	31.0
MIDDLE			44	238.3	150	9.81	6.8	0.85	6.9	13.0	.02	<0.1	65.0	23.0	278	104	46.5
BOTTOM			36	70.2	32.5	9.70	1.72	0.25	2.8	6.20	.01	<0.1	25.0	16.0	123	61.0	29.5

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Table A2 - Continued

SNOW PILE			BOD5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	Na	SO_4	
49 DAYS TOP			24	196.7	57.5	9.74	6.30	0.30	4.6	9.50	0.02	0.2	37.5	12.4	145	46.5	20.5	
MIDDLE			24	185.2	110	9.88	4.90	0.55	4.4	10.5	0.03	0.2	33.5	21.6	173	86.0	39.0	
BOTTOM			15	47.8	55.0	9.17	0.74	0.40	1.3	4.50	0.01	0.2	11.5	11.6	77	48.0	25.0	

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Table A3 Chemical results showing effects of atomization chamber on waste water

DATE	Flow gal/min	BOD_5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F A	Nitrogens Kjel	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	SO_4	Na
Test 1 Raw	80	36	28.7	108	7.66	6.5	3.95	19.5	25	<.01	<0.1	82	25.8	311	33	73
Treated		39	29.2	106	7.54	6.4	3.9	19.4	24	<.01	<0.1	85	25.6	318	33	74
Test 2 Raw	60	38	27.5	107	7.49	6.3	3.9	18.9	23.8	<.01	<0.1	85.5	25.6	319	33	74
Treated		38	26.5	107	7.58	6.35	3.85	18.4	24.3	<.01	<0.1	85.5	25.6	319	32.5	75
Test 3 Raw	36	38	27.1	107	7.62	6.35	3.95	18	23.8	<.01	<0.1	85	25.8	319	31.5	74
Treated		39	26.2	103	7.63	6.25	3.9	17.7	23.8	<.01	<0.1	85.5	25.4	318	32.5	75
Raw	36	42	26.0	105	7.57	6.45	3.95	17.5	24.0	<.01	<0.1	85.5	25.4	318	32.5	74
Treated		37	24.8	108	7.63	6.10	3.9	17.7	23.3	<.01	<0.1	85.5	25.6	319	32	74
Test 4 Raw	55	38	32.3	108	7.49	6.3	4.0	17.5	23.5	<.01	<0.1	84.5	25.4	316	32.5	75
Treated		40	31.4	104	7.59	6.3	3.8	17.5	23.5	<.01	<0.1	85	25.6	318	33	75
Raw	55	42	32.7	108	7.57	6.1	3.9	17.6	24	<.01	<0.1	81.5	24.6	305	32.5	74
Treated		38	33.7	107	7.57	6.4	3.85	17.8	24.5	<.01	<0.1	82	25	308	33	74

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Table A3 - Continued

DATE		Flow gal/min	BOD_5 (mg/l)	Susp. Solids	Chloride	pH	Phosphorus Total	Phosphorus Sol	Nitrogens F.A.	Nitrogens Kjel.	Nitrogens Nitrite	Nitrogens Nitrate	Ca	Mg	Hardness	SO_4	Na	
Raw		55	42	35.2	105	7.52	6.3	4	17.6	24.5	<.01	<0.1	82	25.4	310	32.5	74	
Treated			40	32.4	102	7.55	6.4	3.85	17.9	24.5	<.01	<0.1	82.5	25.2	310	32.5	74	
Raw		55	38	33.5	102	7.57	6.5	3.8	17.9	24.5	<.01	<0.1	82.5	25.4	311	31.5	75	
Treated			38	30.9	102	7.55	6.4	3.9	18.1	24.5	<.01	<0.1	82	25	308	32.5	75	

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BLUE MT. ~ COLLINGWOOD ~ SNOW-MAKING PROJECT

RUN / SITE	RAW SEWAGE - LAGOON					SNOW-MAKING					TOTAL BACT. per m^3	REMARKS
	TC.	BKGD.	FC.	FST.	PSA	TC.	BKGD.	FC.	FST.	PSA.		
31/A						8	12	<4	<4	<4	5.3	
/B	2,200,000	4,600,000	390,000	450,000	C520	G37,000 98.31	90,000	99.84 G600	46.67 240,000	C64	1717.5	GUN 4
32/A						12	200	<4	<4	<4	11.4	
/B	1,300,000	6,000,000	370,000	410,000	C650	G16,000	70,000	99.83 G600	68.29 130,000	<4	1786.2	GUN 4
33/A						<4	<4	<4	<4	<4		
/B	1,400,000	5,500,000	44,000	94,000	<4	1300	8300	32	28,000	<4	333.3	GUN 2
34/A						<4	<4	<4	<4	<4		
/B	1,300,000	6,400,000	33,000	105,000	<4	66,000	21,000	268	31,000	<4	146.3*	*Anaerobic Run GUN 2
						<4	>9600	<4	A10	<4		Snow Pile Top
						<4	>9600	<4	3500	<4		(4 days) Middle
						230	380	<4	500	<4		Bottom
35/A						<4	<4	<4	<4	<4		
/B	5,800,000	3,800,000	32,000	101,000	<4	6000	21,600	8	7000	<4	674	GUN 2.
						8	<4	<4	440	<4		Top } 28-days East Side
						<4	<4	<4	38,000	<4		Middle
						64	32	<4	17,000	<4		Bottom
						<4	<4	<4	470	<4		Top } 28-days West Side
						<4	<4	<4	35,000	<4		Middle
						8	8	<4	A7000	<4		Bottom

SITE A = UPWIND
SITE B = DOWNWIND

Table 4A: continued

BLUE MT. ~ COLLINGWOOD ~ SNOW-MAKING PROJECT.

RUN / SITE	RAW SEWAGE - LAGOON					SNOW-MAKING					TOTAL BACT. per m^3	REMARKS
	TC.	BKGD.	FC.	FST.	PSA	TC.	BKGD.	FC.	FST.	PSA.		
						L10	L10	L10	L10	L4		BACKGROUND [illegible] UPWIND
						L10	L10	L10	L10	L4		BACKGROUND SNOW 35m DOWNWIND
						L10	L10	L10	L10	L4		70m DOWNWIND
1 A						L10	L10	L10	L10	L4	85.6	
1/B	G2,700,000	30,000,000	320,000	G420,000	330	L1,000	L1,000	L1,000	3,300	L10	3718.8	
2/B	4,800,000	7,700,000	220,000	510,000	260	A1,000	4,000	L1,000	85.17 80,000	L10	2931.3	
A						L1,000	L1,000	L1,000	7,300	L10		RUN 2 - 2 DAY [illegible] SNOW MADE
3/—	4,900,000	6,600,000	220,000	G350,000	272	A3,000	65,000	L1,000	41.43 35,000	L10	A = 96.7 B = 3767.2	[illegible] IX
4/A						L4	L4	L4	L4	L4		OLD SNOW
-/B						L4	L4	L4	130	L4		" " - GUN 3
						L4	L4	L4	12	L4		" " - GUN 4
4/A						L4	L4	L4	L4	L4		OLD SNOW
-/B						L4	L4	L4	L10	L4		" " - GUN 3
						L4	L4	L4	L10	L4		" " - GUN 4
4/B	A900,000	1,900,000	480,000	660,000	280	L10	L10	L4	41.42 17,000	L4	A = 6.4 B = 1536.9	GUN 3
						A40	230	11.19 32	75.91 G159,000	L4		GUN 4
5/A						L4	L4	L4	L4	L4	2.5	
5/B	1,400,000	2,400,000	1,100,000	710,000	820	C310	3400	49.19 144	73.24 G190,000	L4	N.A.	GUN 1
						C550	3300	49.98 240	53.52 G330,000	L10		GUN 2
6/A						L10	L10	L4	4	L4	0.0	
6/B	1,000,000	25,000,000	1,500,000	850,000	950	C140	3300	11.19 32	74.49 G210,000	L10	216.3	ATOMIZED GUN 1
						560	1100	11.14 560	76.09 G240,000	L4		ATOMIZED GUN 2
7/A						L4	L4	L4	152	L4	0.0	
7/B	G1,300,000	35,000,000	500,000	910,000	830	5,300	2,100	49.80 110	64.84 G320,000	4	2831.5	GUN 3
						7100	16,000	49.9 140	65.43 G310,000	4		GUN 4

SITE A = UPWIND

SITE B = DOWNWIND

Table 4A: Bacteriological results during the manufacturing of snow from sewage.

BLUE MT. ~ COLLINGWOOD ~ SNOW-MAKING PROJECT

RUN/SITE	RAW SEWAGE - LAGOON					SNOW-MAKING					TOTAL BACT. per m^3	REMARKS
	TC.	BKGD.	FC.	FST.	PSA	TC.	BKGD.	FC.	FST.	PSA.		
						28	4	L4	4	L4		OLD SNOW - GUN 1
						12	800	8	G600	L4		" " - GUN 2
						12	88	L4	G600	L4		" " - GUN 3
						8	4	L4	20	L4		" " - GUN 4
						L4	L4	L4	L4	L4		OLD SNOW - UPWIND
						L4	L4	L4	L4	L4		" " "
8/B	24,000,000	22,000,000	140,000	450,000	A400	520	1,700	99.94 A90	75.56 110,000	L4		GUN 1
						1600	22,200	99.98 24	77.78 100,000	L4	1768.4	GUN 1
8/A						L4	L4	L4	L4	L4	2.5	
9/A						L4	L4	L4	4	L4	2.5	
9/B	8,200,000	12,000,000	130,000	340,000	A40	L10	L10	99.99 L4	84.41 53,000	L4	1241.7	GUN 1
						A10	1100	99.99 4	87.06 44,000	L4		GUN 1
10/A						L4	L4	L4	L4	L4	7.6	
10/B	10,000,000	24,000,000	A60,000	340,000	A20	C1300	39,000	99.9 A60	64.71 120,000	L4	1198.5	GUN 2
						C 140	G24,000	99.98 A10	17.65 280,000	L4		GUN 2
11/A						L4	4	L4	L4	L4	0.0	
11/B	8,600,000	13,000,000	140,000	490,000	A20	C1400	48,000	99.93 100	71.43 140,000	L4	1333.3	GUN 2
						C2200	100,000	99.92 110	53.06 230,000	L4		GUN 2
12/A						L4	L4	L4	L4	L4	1.3	
12/B	8,200,000	8,000,000	A80,000	500,000	A20	A1,000	4,000	99.29 570	52.0 240,000	L4	590.3	GUN 2
						G1,500	1,900,000	98.13 G1500	44.0 280,000	4		GUN 2
13/A						L4	L4	L4	L4	L4	5.2	
13/B	7,200,000	8,100,000	200,000	520,000	C120	660	12,000	99.67 660	73.08 140,000	L4	668.7	GUN 2
						C820	G24,000	99.59 820	87.69 64,000	L4		GUN 2

SITE A = UPWIND

SITE B = DOWNWIND

Table 4A: continued

BLUE MT. ~ COLLINGWOOD ~ SNOW-MAKING PROJECT

RUN / SITE	RAW SEWAGE - LAGOON					SNOW-MAKING					TOTAL BACT.	REMARKS
	TC.	BKGD.	FC.	FST.	PSA	TC.	BKGD.	FC.	FST.	PSA.	per m^3	
						450	G24,000	450	60,000	L4		OLD SNOW 1-day
						C700	G24,000	700	62,000	L4		OLD SNOW
14/A						L4	40	L4	L4	L4	1.7	
14/B	5,600,000	11,200,000	180,000	350,000	A90	C144	1,700	[99.92] 144	[96.86] 11,000	L4	2589.1	GUN 1
						1,000	1,000	[99.76] 440	[87.43] 44,000	28		GUN 2
15/A						L4	L4	L4	L4	L4	0.0	
15/B	4,200,000	8,300,000	120,000	390,000	110	A600	1,300	[99.81] 230	[88.72] 44,000	L4	4231.6	GUN 1
						C530	11,000	[99.56] 530	[91.54] 33,000	L4		GUN 2
16/A						L4	L4	L4	L4	L4	3.1	
16/B	5,100,000	8,400,000	130,000	270,000	A80	1,000	13,000	[99.8] 260	[80.74] 52,000	L4	2385.5	GUN 1
						1,300	10,000	[99.53] 610	[98.52] 4,000	L4		GUN 2 (1-day)
						L10	L10	L10	G21,000	L4		OLD SNOW - TOP 10cm
						A30	20	L10	G360,000	L4		" " - MID 10cm
						160	20	L10	G18,600	L4		" " - BOTT. 10cm
17/A						L4	L4	L4	L4	L4	7.6	
/B	8,800,000	18,000,000	270,000	540,000	C620	C750	G24,000	[99.96] 96	[89.26] 58,000	C20	2055.9	GUN4
18/A						L4	L4	L4	L4	L4	2.5	
/B	1,000,000	7,300,000	270,000	520,000	C770	C900	G24,000	[99.98] A60	[44.23] 290,000	L4	3992.3	GUN4
19/A						L4	L4	L4	L4	L4	0.0*	
/B	A400,000	1,120,000	260,000	360,000	C680	C8,200	55,000	[99.91] 240	[30.56] 250,000	L4	2611.9*	GUN4
20/A						L4	4	L4	L4	L4	2.5	
/B	LAB. ACCIDENT		320,000	440,000	C650	C570	G24,000	[99.79] A20	[59.10] 180,000	L4	2664.1	GUN4
21/A						L4	L4	L4	L4	L4	5.0	
/B	C11,400,000	22,000,000	480,000	540,000	C820	L10	L10	[99.99] L4	[99.63] A2,000	L4	486.0	GUN2 - WET SNOW
						L10	L10	[99.99] L4	[97.04] 16,000	L4		GUN4 - DRY SNOW

SITE A = UPWIND
SITE B = DOWNWIND

* ANAEROBIC INCUBATION

Table 4A: continued

BLUE MT. ~ COLLINGWOOD ~ SNOW-MAKING PROJECT

RUN / SITE	RAW SEWAGE - LAGOON TC.	BKGD.	FC.	FST.	PSA	SNOW-MAKING TC.	BKGD.	FC.	FST.	PSA.	TOTAL BACT. per m^3	REMARKS
22/A						L4	L4	L4	16	L4	5.0	
22/B	8,500,000	27,000,000	450,000	620,000	C780	C700	4100	99.99 L4	83.31 72,000	8	708.6	GUN 2
23/A						L10	10	99.99 L4	96.17 20,000	4		GUN 4
						L4	L4	L4	L4	L4	3.8	
23/B	2,800,000	14,100,000	530,000	380,000	C960	C570	G24,000	99.99 40	83.42 63,000	L4	4171.7	GUN 2
24/A						G30,000	45,000	G600	94.74 20,000	C72		GUN 4
						L4	L4	L4	L4	L4	2.5	
24/B	4,100,000	15,700,000	490,000	390,000	C110	C3,700	28,000	99.91 430	74.36 100,000	L4	3136.0	GUN 2
25	10,400,000	21,000,000	350,000	660,000	C1200	C 450	6,400	L10	97.86 G600	L4		GUN 4
26/A						FIELD ACCIDENT						
						L4	L4	L4	L4	L4	10.1	
26/B	3,200,000	31,000,000	420,000	590,000	G1500	C5,600	41,000	1,010	83.05 100,000	L4	2002.5	GUN 2
						C5,400	33,000	99.94 230	590,000	4		GUN 4
						A20	110	L4	1,400	L4		
						A10	480	L4	10,800	L4		SNOW PILE - TOP 10 cm
						C30	3,000	L4	10,200	L4		" " - MID 10 cm
27/A						44	12	L4	4	L4		" " - BOTT. 10 cm
/B	4,600,000	7,000,000	620,000	520,000	C456	1,400	21,400	99.90 G600	99.99 12	L4	10.1	
28/A						8	L4	L4	66,000	L4	2569.9	GUN 4
/B	LAB. ACCIDENT		580,000	620,000	C610	L10	3000	99.99 L4	94.35 35,000	L4	10.1	
29/A						L4	L4	L4	L4	L4	4198.4	GUN 4
/B	1,400,000	3,800,000	240,000	280,000	C540	G30,000	120,000	99.75 G600	200,000	20	12.7	
30/A						L4	L4	L4	L4	L4	1680.6	GUN 4
/B	1,000,000	4,600,000	300,000	290,000	C530	G42,000	110,000	G600	140,000	C92	0.0*	
											241.7*	GUN 4

SITE A = UPWIND
SITE B = DOWNWIND

* ANAEROBIC INCUBATION

Table 4A: continued

APPENDIX B

PERCENT RECOVERY

Table B1. Percent recovery of bacterial colonies on a selective medium replicated from nutrient agar

Organism	Number of Colonies on Nutrient Agar	Number of Colonies on Selective Agar	% Recovery
Escherichia coli	156	132/125 (Endo les Agar)	82.4
Streptococcus fecalis	13	13/13 (m-Enterococcus Agar)	100.0
Escherichia coli	34	34/34 (mTec Agar)	100.0
Pseudomonas aeruginosa	15	13/13 (mPA Agar)	86.7
Salmonella sp.	112	96/84 (Brilliant green Agar)	80.4
Staphylococcus aureus	44	42/42 (Mannitol Salt Agar)	95.4

Plate 2: Pictures showing the replicate plate procedure for the recovery of indicator and pathogenic bacteria.

APPENDIX C

LIST OF BACTERIOLOGICAL MEDIA USED

APPENDIX C

Table C1. Media used in bacteriological analyses.

Bacterial Type	Medium	Incubation Temperature °C	Incubation Period h.
Coliforms	m-Endo les agar	35.0	24
Fecal Coliforms	m-Tec agar	44.5	24
Fecal Streptococci	m-Enterococcus agar	35.0	24
Pseudomonas aeruginosa	m-PAE agar	41.5	28
Salmonella sp.	Brilliant Green - Sulfa agar	41.5	48
Clostridium perfringens	CP agar	35/44.5	2 and 22
Staphylococcus aureus	Mannitol Salt agar	35.0	24
Klebsiella pneumoniae	m-K agar	35.0	24

APPENDIX D

OVERVIEW

As mentioned earlier in this report, this experimental project was conducted to determine the feasibility of making snow from sewage or lagoon wastewater as a sewage treatment alternative. The manufacturing of snow during the freezing periods of the year is one part of a possible overall year-round disposal concept.

The overall concept is the year-round treatment and disposal of sewage using compressed air and modified snow-making equipment. The system would operate in a snow-making mode during freezing periods of the year and in a modified spray irrigation mode in the non-freezing periods of the year. It would always be treated on a batch concept following lagooning or clarification to remove large solids and then sprayed on a prepared bed. Presumably, this prepared bed would provide filtration and a site for further bacteriological and biological reduction of the waste during non-freezing periods of the year. The bed can be under-drained depending on surrounding soil conditions or ultimate disposal options. Disinfection of the waste can be done to reduce bacterial concerns in respect to aerosols and/or effluent discharges.

More literature is available on spray irrigation than on snow making and it is this paucity of information that is in part the reason for the two-year experimental project. If this phase looks promising after two years of study, consideration can be given to the building of a pilot plant for year-round operations.

The proposed capital costs for this type of treatment facility are hard to determine because, like other

sewage treatment systems, they depend on sewage volumes, soil conditions, discharge criteria, etc. However, the proposed costs generated by the consultant would make this system cost competitive with facultative lagoons and cheaper than winter aerated lagoons, comparing similar sizes. No actual dollar values are shown because of the dissimilarities in what ideal soil conditions, etc. are for the respective treatment systems. For a facultative lagoon, clay soils are ideal, while under this proposal, lighter soils would be considered ideal. After a pilot plant is built and operational, more detailed costs can be calculated.

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